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EUROPEAN SCIENTIFIC NOTES,(U)
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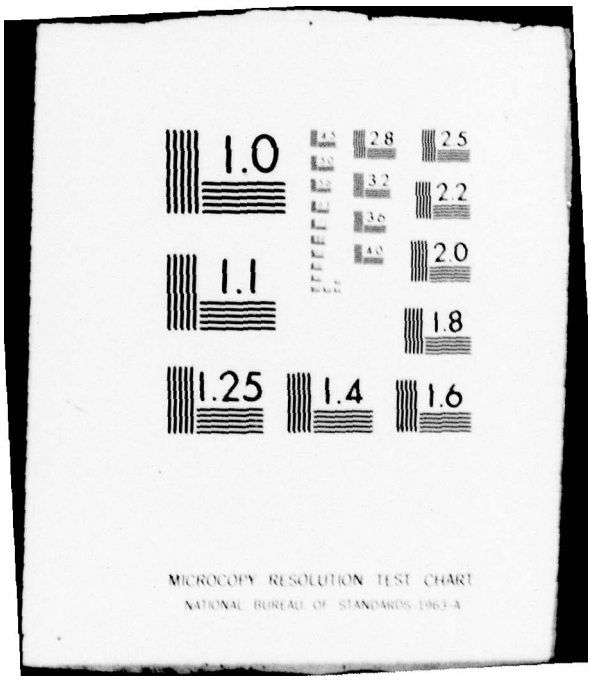
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LEVEL II

EUROPEAN SCIENTIFIC NOTES

ESN 33-6

30 June 1979

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: ESN - 33-6 (14)	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): EUROPEAN SCIENTIFIC NOTES (6)	5. TYPE OF REPORT & PERIOD COVERED: Monthly Publication, June
6. PERFORMING ORG. REPORT NUMBER: ESN 33-6	
7. AUTHOR(s): (10) Irving Victoria Kaufman [redacted] S. Hewitson, editors	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Office of Naval Research Branch Office London, Box 39, FPO New York 09510	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS (11)	12. REPORT DATE: 30 Jun [redacted]79
	13. NUMBER OF PAGES: 43
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 49 p.	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

ATMOSPHERIC SCI	MATERIAL SCI
BIOENGINEERING	MEDICINE
COMPUTER SCI	PHYSICS
ENERGY	OPERATIONAL RESEARCH
FLUID MECHANICS	SPACE SCI

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a monthly publication presenting brief articles concerning recent developments in European Scientific Research. It is hoped that these articles (which do not constitute part of the scientific literature) may prove of value to American scientists by calling attention to current developments and to institutions and individuals engaged in these scientific efforts.

The articles are written primarily by members of the staff of ONRL and occasionally articles are prepared by, or in cooperation with, members of the

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scientific staffs of the United States Air Force's European Office of Aerospace Research and Development and the United States Army Research and Standardization Group. Articles are also contributed by visiting Stateside scientists.

EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Edited by: Irving Kaufman and Victoria S. Hewitson

30 June 1979 Volume 33, No. 6

European Scientific Notes is a Class I Periodical prepared and distributed by the Office of Naval Research London in accordance with NAVEXOS-P-35. Prepared and submitted by the scientific and technical staff.

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ATMOSPHERIC SCIENCES

LASERS OVER ROME

Professor Giorgio Fiocco (Istituto di Fisica "Guglielmo Marconi," Università di Roma, Italy) pioneered the use of lidar for remote measurement of stratospheric aerosols [see G. Fiocco and G. Grams, *J. Geophys. Res.* 74, 2453 (1969)]. Fiocco's early work was done while he was in the US at MIT, but he later returned to Italy to continue his lidar work. Now, in addition to his university professorship, he is also Director of the Istituto per la Fisica dell'Atmosfera, a Consiglio Nazionale delle Richerche (CNR) laboratory at Frascati.

Fiocco's early lidar work in the US was based on the use of pulsed ruby lasers for measurement of particulates in the upper atmosphere. More recently, however, he has become interested in Doppler lidar techniques for remotely measuring particulate and molecular velocities in the troposphere. His instrumentation incorporates an Ar-ion, cw-laser whose output is chopped by a high speed wheel with holes that rotates in a vacuum. Output pulses are about 1-μsec in duration which corresponds to a range resolution of 150 m. The lidar receiver consists of a 50-cm-diam. telescope, scanning spherical Fabry-Perot interferometer (SFP), cooled photomultiplier, and photon counting electronics. The SFP is used to determine the spectrum of the backscattered laser radiation. In general, this spectrum consists of a broad background arising from scattering from molecules on top of which is superimposed a narrow peak produced by aerosols. Figure 1 illustrates the concept. The radial wind velocity is determined from the frequency shift between the transmitted frequency and the aerosol peak. Fiocco, together with colleagues, G. Benedetti-Michelangeli and F. Congeduti has extended this technique to determinations of the vertical eddy flux and diffusion coefficient of aerosols. These measurements require simultaneous knowledge of the vertical aerosol velocity component w, which is equivalent to the vertical wind velocity, and the aerosol concentration. These quantities can be determined from the spectrum of the Doppler lidar signal (Fig. 1). By a comparison of the intensities of aerosol and molecular signals, the ratio p of total backscatter cross sections is obtained:

$$p = \Sigma_i N_{A,i}\sigma_{A,i}/\Sigma_j N_{M,j}\sigma_{M,j}$$

where $N_{A,i}$ is the concentration of aerosols of type i, $N_{M,j}$ is the concentration of molecules of type j, $\sigma_{A,i}$ is the backscatter cross section of aerosols of type i, and $\sigma_{M,j}$ is the backscatter cross section of molecules of type j. The instantaneous values of w and p can be written: $w = \bar{w} + w'$ and $p = \bar{p} + p'$ where the terms on the right-hand side of the equations are mean and fluctuating components, respectively. The instantaneous vertical flux is given by the product wp. The mean value of wp is: $\overline{wp} = \bar{w}\,\bar{p} + \overline{w'p'}$, since $\overline{w'}$ and $\overline{p'}$ are zero. The quantity $\overline{w'p'}$ is the turbulent flux which can be written: $\overline{w'p'} = -K\partial\bar{p}/\partial Z = -K\bar{p}/H$ where K is the eddy diffusion coefficient and H is a mixing length. The lidar signal provides values for w'p', $\partial p/\partial Z$, and p from which K and H can be calculated.

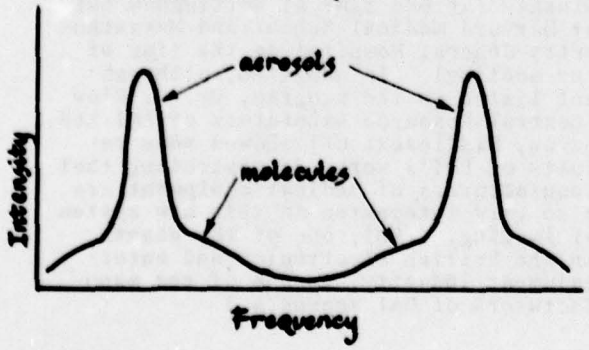


Figure 1.

Several measurements were made at Frascati earlier for three, 300-m height ranges centered at 225, 375 and 675 m. Values of eddy diffusion coefficient and power spectra of p, w, and wp were obtained. These results were preliminary but indicate that the Doppler lidar can be useful for analyzing atmospheric processes. On the basis of these results, Fiocco has improved the lidar by increasing the laser power to about 15 W, increasing the modulation rate, and thus permitting finer height resolution, and improving the data processing. Under average conditions a maximum range of 1.5 km is obtainable. Systematic measurements have been carried out for several months, and now the group is analyzing the results.

Fiocco, along with G. Visconti and G. Grams (Georgia Institute of Technology, Atlanta), has been interested recently in the effects of aerosols in changing the temperature of the upper atmosphere (50-110 km). The aerosols absorb solar radiation, exchange energy by collisions with gas molecules, and emit thermal radiation. Additionally, if a phase change takes place, latent heat is lost or gained. Significant temperature differences can exist between the particles and the molecules. They can be warmer by as much as 100 K in daytime and colder at night. Fiocco and his coworkers believe aerosols can influence upper atmosphere behavior if the concentration is high enough. They have calculated heating rates and equilibrium (energy rate balance) temperatures for aerosol models, and believe that in some instances aersols could have produced heating rates greater than 1 K day^{-1} at an altitude of 67 km while the combined heating rate due to CO_2 and O_3 can be less than 1 K day^{-1} at that altitude. The 67-km altitude was used because of some lidar measurements made by Fiocco and Grams several years earlier that showed that a mesospheric aerosol layer existed then at an altitude around 67 km. The aerosol scattering from this layer exceeded the Rayleigh molecular scattering by a factor of four.

The same authors later extended their analysis to the 0-60 km region, and concluded that during the volcanic eruptions of Mt. Agung in 1963 and Fuego in 1974 aerosols could have produced heating rates of 1 K day^{-1} at the 15- to 25-km altitude range in the equatorial regions for a year or so after each eruption.

Fiocco's group is well equipped, particularly with lidar instrumentation for measurements in the troposphere, stratosphere, and upper atmosphere. A good balance of theoretical and experimental work is being carried out on specialized areas of atmospheric physics. Interestingly however Fiocco voiced a complaint I have heard several times from Italian scientists—that they have difficulty obtaining experienced engineers or technicians. They must hire new, inexperienced help who must be trained from scratch. This puts a strain on the scientists who often must do much of their own instrument construction and writing of computer programs, etc. (Vern N. Smiley)

BIOENGINEERING

NMR IMAGING—SUBSITUTE OR SUPPLEMENT FOR X-RAY AXIAL TOMOGRAPHY?

Medical diagnosis by x-rays has been a standard technique for a long time. In very recent years this technique has been greatly enhanced by the CAT x-ray scanner ("Computerized Axial Tomography"), which combines x-ray techniques with fast computation to produce tomograms, i.e., two-dimensional outlines of structure along essentially any plane desired.

While x-ray diagnosis is virtually indispensable in modern medicine, it has one drawback: It is an ionizing radiation.

Although it is still too early to tell, a new technology may well be on the way that will provide images similar to those obtained with x-ray CAT scanners, but without the ionizing radiation. This is NMR, nuclear magnetic resonance imaging. First suggested by P.C. Lauterbur (State University of New York at Stony Brook) in 1973 as a specific example of zeugmatography, a term used to designate image formation through the coupling of two fields by the object that is being imaged, the technique is now under investigation in a number of laboratories.

Considerable progress has been made since Lauterbur's first publication. The present status of this field, with specific emphasis on work in several laboratories in the UK, was the subject of a recent evening meeting in London that was sponsored by the Joint IEE/IERE Medical and Biological Electronics Group and the British Institute of Radiologists. Speakers were Prof. J. Mallard (Univ. of Aberdeen), Prof. E.R. Andrew and Dr. P. Mansfield (Univ. of Nottingham), and Prof. W.S. Hinshaw (at one time at Nottingham but at Harvard Medical School and Massachusetts General Hospital at the time of the meeting). In addition, although not listed on the program, Dr. H. Clow (Central Research Laboratory of EMI Ltd., Hayes, Middlesex, UK) showed some results of EMI's work, demonstrating that manufacturers of medical equipment are also very interested in this new system of imaging. (EMI, one of the giants in the British electronics and entertainment industry, is one of the manufacturers of CAT scanners.)

NMR has been a well-established technique for analytical, structural, and dynamical investigation of matter for the last 30 years. At various times these Notes have reported on scientific investigations with NMR (Cf. *ESN* 29-4: 154,155,157).

Since NMR imaging techniques may be of interest to readers who are not currently engaged in NMR work, we briefly review some of the principles and techniques involved.

NMR techniques exploit the fact that protons (and some other nuclei) act like miniature spinning magnets (often called spins) which, when placed in a magnetic field, behave much like inclined spinning tops that, while rotating about their own axes, also precess around a central axis. Instead of rotating around a gravitational axis, however, as the top does, a spin precesses around the direction of the local magnetic field line, and it does so with an angular velocity $\omega_o = \gamma B$. Here γ, the "gyromagnetic ratio," is a constant of the spinning particle, B is the intensity of the magnetic field. Angular velocity ω_o is sometimes called "the angular frequency of magnetic resonance of the spin." The phenomenon also applies to other particles, each with its own value of γ. For protons or other nuclei the technique is called "nuclear magnetic resonance," or "NMR."

For protons in a magnetic field of the easily achieved intensity of 0.1 T (1000 G), $\omega_o = (26.8)(10^6)$ rad/sec, corresponding to $(4.26)(10^6)$ revolutions/sec. In electrical terminology this is a frequency of 4.26 MHz.

The angle that the axis of the spin makes with the direction of the magnetic field B is a measure of the energy of the system. Thus, nearly parallel orientation of the axis of the spinning proton to the direction of the steady magnetic B-field corresponds to low potential energy. An angle of 90° between the axis and the B-field means more potential energy, and anti-parallel orientation is an even greater amount. To "pump" a spinning proton into a 90° orientation from the parallel orientation, one applies a time-varying magnetic field whose direction is transverse to constant B-field and whose frequency is the frequency of NMR.

Since nature generally seeks to bring a system to its state of lowest energy, a proton placed into a B-field not parallel to its axis will gradually "relax" to the parallel orientation. If completely isolated, the "relaxation time" will be extremely long, since energy can then only be lost through electromagnetic radiation—a most inefficient process here. When surrounded by other matter, however, such as the molecules of water, the additional interaction with the other particles reduces the relaxation time to the order of a second or less. Moreover, when in such an environment, the frequency of NMR also depends somewhat on the enviromental properties.

The presence of an aggregate of processing protons can be detected by a nearby coil of wire. This is because this aggregate produces a small magnetic field that rotates in space, so that an ac voltage of the frequency of precession appears across the terminals of the coil. In this manner, both the frequency of NMR and the relaxation time can be measured.

The small but measurable shifts in the NMR frequency and in the relaxation time, mentioned above, can be related to the material structure. NMR therefore became a standard technique for chemical and physical analysis some time ago.

One sometimes speaks of the aggregate of the spinning protons, whose magnetic fields add vectorally to give a net oriented magnetic dipole density as the "magnetization" of this aggregate. Since the spins precess about the axis that is the direction of the static magnetic field, one speaks of a longitudinal component of the magnetization (parallel to the field) and a transverse magnetization (perpendicular to the field). Similarly, one observes both a longitudinal relaxation time, T_1, and a transverse relaxation time, T_2. For a mobile, liquid material, such as pure water, T_1 and T_2 are each about 1 sec. In a rigid material, T_1 lengthens and T_2 shortens. Now, it turns out that in one measurement scheme the signal obtained varies approximately as the ratio $T_2/(T_1 + T_2)$. Referring to the analysis of organic tissue, therefore, soft tissue, with a highly mobile proton density, will give a strong signal; bone tissue will give a weak signal. NMR techniques offer therefore a way of distinguishing between various types of tissue.

Since the proton mobility would be expected to change if the tissue changes, one could also expect differ-

ences in T_1 and/or T_2 between normal and abnormal tissue. Indeed, it has been found that tissue of malignant tumors can have values of T_1 considerably larger than healthy tissue of the same type. These phenomena suggest the use of NMR for medical diagnosis. If only a way could be found for doing *in vivo* NMR mapping of portions of the human body, perhaps NMR techniques could be developed to replace or supplement x-ray analysis.

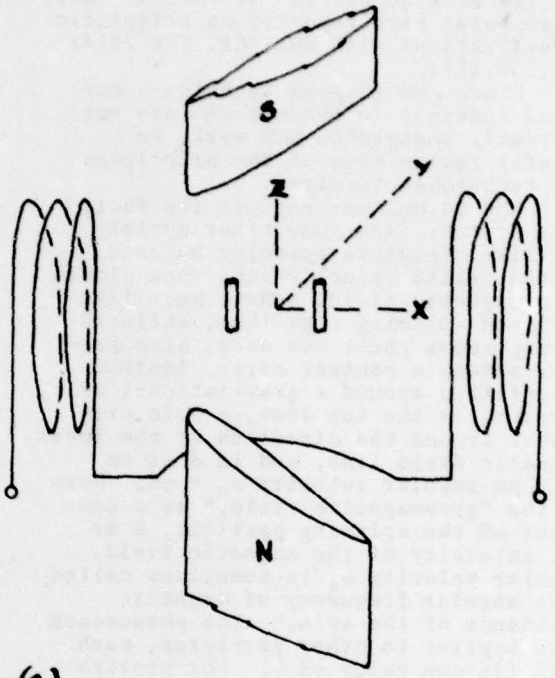
As stated earlier, a start toward such developments was disclosed by Lauterbur in 1973, with a scheme similar to that of Fig. 1. Here two vials of water are placed in a vertically directed dc magnetic field whose intensity varies along the x-direction. By sweeping slowly through a frequency range or by changing the magnetic field in time in such a system, two resonant peaks are detected by the coil, each corresponding to NMR at the location of one of the vials of water. An alternate technique would be to start with a spatially constant magnetic field, "pump" the spins into, say, the 90° orientation, then apply an additional small, z-directed magnetic field whose intensity varies in the x-direction and sense the signal arising from the relaxation of the spins. Spectral analysis of the signals obtained by, say, fast Fourier transform techniques results in amplitude and phase information that gives a direct measure of spatial spin density and relaxation times.

Now, suppose the direction of the magnetic gradient is along the y-axis. Since both vials now experience the same magnetic field, only one resonance peak, larger than each of the two previous ones, will be obtained. If the gradient in B-field were in some other direction, such as in the xy-plane and 45° with respect to the x-axis, two peaks would again be found, though of different intensity and spacing than earlier.

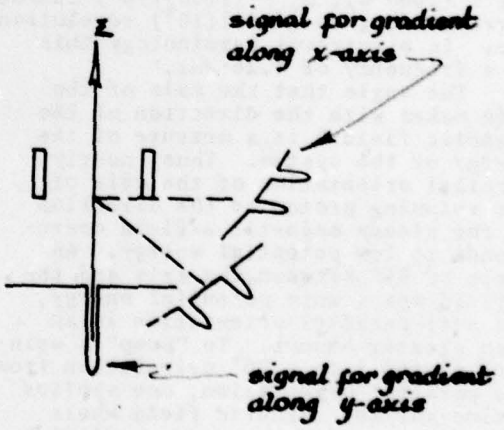
Since the NMR signals found can be thought of as projections along various directions, they may be combined by the type of computer techniques used in the CAT scanner. This is shown schematically in Figs. 1(b) and 1(c).

In the above, the measurement was of NMR frequencies. By a modification of the method, a map of the relaxation times could similarly be obtained.

Figure 1.



(a)



(b)

pixels obtained by computer reconstruction from signals of (b)

(c)

In the IEE/IERE/BIR presentation, Mallard and Andrew explained the basic principles, as sketched above, as well as some of the improvements that have been devised. One obvious extension to a full three-dimensional description of an object can be performed by taking N^2 projections along directions distributed isotropically, each of N data points. A computer then combines these N^3 numbers and calculates the density in a three-dimensional array of N^3 "voxels."

This, in fact, has been done. However, since the technique becomes a formidable and expensive computer task, other techniques have been devised.

The so-called "spin-mapping" method uses three orthogonal field gradients to define a small volume, whose signal is picked out by filtering. By successive scanning through a specimen, the proton density can be plotted without the need of expensive computer reconstruction. In addition, the method may be speeded up by scanning a plane of elements line by line. This scheme was devised by Hinshaw, who named this technique the "multiple sensitive point (MSP) method." Some other NMR mapping techniques are known as the "selective irradiation method," "Fourier zeugmatography," and "fonar" (focused nuclear resonance).

An example of an NMR image, published by Hinshaw et al., is given in Fig. 2. Here an NMR image of a live human wrist (top) is compared with the actual known structure of such a wrist (bottom). The possibly great potential of the technique is immediately evident from this figure.

A calendar of the progress of NMR imaging starts with Lauterbur's tubes of water in 1973. These were followed by images of a spring onion (1974), human finger (1975), human hand (1976), and human chest (1977). A magnet structure to contain the abdominal portion of the human body and therefore of potential for obtaining NMR tomographs of any section of the human body is currently under construction in the laboratory of Mallard at Aberdeen. Similarly, Andrew and Mansfield discussed the magnet used for whole-body imaging at Nottingham. It stands 2 m high, has a patient access of 60 cm, weighs 2000 kg and has a water-cooled magnet that develops an axial B-field of 0.1 T.

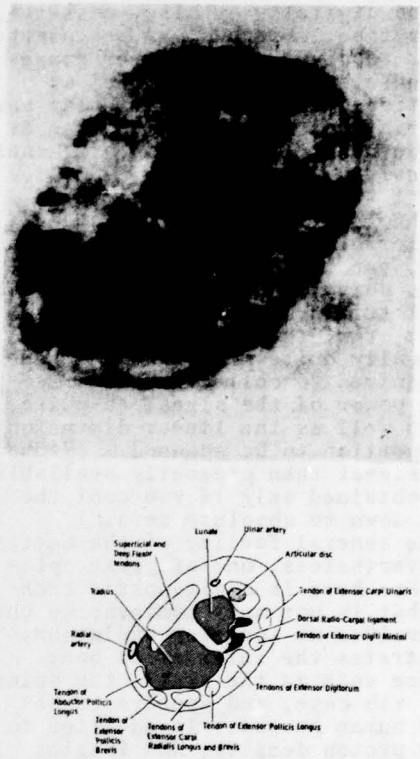


Figure 2. This figure is from the article "An *in vivo* study of the fore-arm and hand by thin section NMR imaging," by W.S. Hinshaw, E.R. Andrew, P.A. Bottomley, G.N. Holland, W.S. Moore, and B.S. Worthington, *British J. Radiology*, Vol. 52, 36-43 (1979). Permission to reproduce this figure by Prof. Andrew and by *The British Journal of Radiology* is gratefully acknowledged.

As with other imaging methods, NMR images may be displayed in a variety of ways, such as on an oscilloscope, a photograph, a pen recorder, or a photoscanner. They may be presented in black and white or in color. The data may

be stored digitally on disc, cassette, or paper tape. Windows may be inserted in order to display particular ranges of response. Color may be used as an additional parameter to display spatial variations of relaxation time or some other facet, preserving brightness of intensity.

Lest the audience embrace this new technology as the great panacea for all problems in medical diagnosis, Hinshaw, one of the pioneers in NMR imaging, pointed out that no full-scale clinical trials have as yet been carried out, that the signals obtained are actually quite weak, and that the time required to collect data varies as some power of the signal-to-noise ratio as well as the linear dimension of the portion to be scanned. ("A much better signal than presently available can be obtained only if you cool the patient down to absolute zero.")

The general feeling of the meeting was, nevertheless, one of great optimism. For here is a diagnostic technique that is not only noninvasive but also involves no ionizing radiation. It penetrates the interior of bony structure such as the skull, the spine, and the rib cage, and appears to be without human hazard. In addition to mapping proton density, NMR imaging also offers to map other characteristics of tissue, such as the relaxation times, and blood flow velocity, and it can discriminate against anomalous tissue. Moreover, although the favorite nucleus for NMR imaging to date has been the proton, which is in hydrogen atoms, wherever they are to be found, some work has also been done on ^{19}F. Other nuclei, such as ^{2}D, ^{13}C, ^{23}Na, and ^{31}P, remain to be explored. It was thought that with the current energetic activity in a number of university laboratories and the interest now being shown by the medical instrumentation industry, exciting developments could be expected in NMR resonance imaging during the next few years. (Irving Kaufman)

COMPUTER SCIENCE

INFORMATICS AT THE UNIVERSITY OF PARIS-SOUTH

On 17 January 1978 I visited Professor Erol Gelenbe and his associates at the Univ. of Paris-South (UP-S) located in Orsay, about 10 miles south of Paris on a relatively new campus. Gelenbe is Director of the Laboratory for Research in Informatics (LRI) at the University and well recognized for his work in distributed data processing and distributed data bases. After providing me with an overview of computer science research in the region of Paris, Gelenbe and his colleagues briefed me on distributed systems, local network research, and program synthesis. Following is a summary of what I learned:

According to Gelenbe's account, what is presently UP-S was previously located in Paris as a branch of the University of Paris VI (Pierre and Marie Curie). It is now a separate institute, with campuses located in Orsay and Chatenay-Dalabry, but remains almost entirely a technical university. The Faculty of Science and a small Faculty of Law are located in Orsay, while the Faculty of Biomedical Science is located in Chatenay-Dalabry. The Faculty of Science numbers 2000 including full-time research workers, technicians, and clerical assistants. There are only 8000 students on the Orsay campus thus limiting the teaching load to merely 75 hours/year and freeing the faculty to concentrate on research.

The University is organized horizontally by level of study, rather than vertically by discipline. That is, there is a Faculty for Graduate Work and Research (UER Troisième Cycle) and a separate Faculty for Undergraduate Work. The director of the (graduate) Institute for Computer Science is Dr. Mercouroff, formerly the Director of Computer Science for the entire French Ministry of Education. Within the Institute for Computer Science are several laboratories concerned with computer science, one of these being Gelenbe's LRI, which was established very recently, in October 1977. There are also laboratories in Statistics and Numerical Analysis.

Outside the University, but nearby, are a laboratory run by the CNRS (the National Center for Scientific Research, France's equivalent to our National Science Foundation) called LIMSI (Laboratory of Applied Informatics in Mechanical Science and Engineering), a laboratory in Applied Mathematics and Numerical Analysis at the Ecole Polytechnique, and a hardware-oriented Computer Science Laboratory within the SUPELEC (Ecole Supérieur, or Engineering School).

As this proliferation of laboratories might indicate, the area is rich in computers. On campus there are two computer centers, one operated by CNRS called CIRCE containing an IBM 370/168 large-scale computer in a time share mode, and the other operated by the University and called Paris Sud Informatique (PSI), with a Univac 1110 Tri-Processor and an 1108 front end, which is used in both batch and time share operations. In addition, there are at least ten computers on the UP-S campuses, including an IBM 370/138 medium scale computer at the Institute for Nuclear Physics; and within LRI there is a French MITRAC 125.

Gelenbe indicated that UP-S is regarded as the richest, and possibly the best scientific university in France, but before going into further detail on LRI's role in UP-S he felt it was desirable to identify two other organizations outside the immediate vicinity, with which LRI has close relationships. First of all, within the French postal system there is, under the Director-General for Telecommunications, a research establishment roughly analogous to Bell Laboratories, which has a staff of about 3500 and is called CNET. Slightly fewer than half of the staff are located at Issy, near Paris, and an approximately equal number (about 1500) are at Lannion in Brittany. There is also a semiconductor establishment of about 500 people at Grenoble and a small nucleus at Rennes. CNET performs research in-house and also supports research at various universities.

Within the Ministry of Industry is the Institute for Research in Informatics and Automation (IRIA) which is located in Rocquencourt outside Versailles. IRIA is perhaps half the size of CNET. Like CNET, it both performs in-house research and issues research grants to universities. IRIA also conducts pilot projects, as no doubt does CNET. IRIA is organized into three parts, the Pilot Project administration (of which one project is M. Louis Pouzin's EURONET project), an administrative group called SESORI which issues research grants to universities, and the IRIA research laboratory. Gelenbe and another UP-S faculty member Prof. Vueillmin each head a department in the IRIA laboratory. Gelenbe directs work in performance analysis while Vueillmin directs work in complexity.

Thus, to summarize, several ministries of the French national government are active in the field of Computer Science: The Ministry of Education has established Computer Science Faculties at Paris VI, Paris-South, Rennes, Nancy, Grenoble and Toulouse, and, of course, supports applied computer science activities at other locations as well. The Ministry of Industry operates IRIA. The Ministry of Posts, Telephones, and Telegraphs operates CNET. Moreover, it should be mentioned that the CNRS supports research laboratories' and universities' work in computer science, as does the Ministry of Defence.

Since all of these are government agencies, it may come as no surprise that the necessary support must take the form of both funds and authorization to hire staff. The French government, like the US government, controls each separately, establishing budgets and billets (called "Postes"). Both funds and Postes may thus be provided when CNET supports research, and all Postes are fully paid by government funds. It proves quite complex and difficult for a university to engage graduate research workers except into authorized Postes, and so there is almost no interest in the search for grant money to pay employee salaries. The exceptions to this are for visiting scientists, or part-time employees—and the latter, of course, are usually clerical.

Grants must be signed by the president of the university if they are fully accepted. But after acceptance, the Principal Investigator's signature is also required for expenditures. University overhead is 4 or 5% and, usually there is also a laboratory overhead of 10%.

We now return to the Laboratory for Research in Informatics. LRI contains a professional staff of about 25 and is, as has already been mentioned, only two years old. It receives its support from the University (which is

to say the Ministry of Education), CNRS, and a group of long-term associations with other government agencies (such as CNET) and industry. CNRS issues a block grant to LRI annually, which includes Postes for scientific, technical, and clerical personnel, and funds for additional operating expenses. CNRS grades the laboratories of France, and places LRI in the top 33%. Gelenbe indicated that LRI has received "top money" from CNRS, which sounds as though LRI is one of the biggest grantees of CNRS. LRI also receives a block grant from the University. This provides Postes for 20 scientists. In addition, it obtains support from CNET, IRIA, and industry.

Probably LRI's closest industrial connection is with IBM-France, which hires three LRI graduate students each year and maintains one IBM senior engineer at the Laboratory to do thesis work. LRI also has close working relationships with several purely French firms. GIXI, formerly the computer department of the French Atomic Energy commission and now a commercial undertaking, is collaborating with LRI in the construction of a local area network of LRI design. LMT, a division of Thompson-CSF, has provided grants, and CII-Honeywell Bull is supporting LRI work on performance evaluation of distributed data bases.

A tabular summary of LRI postes, and how they are provided, might look like this:

Source	Scientific	Technician	Clerical	Total
University	20	1	1	22
CNRS	3	-	1	4
CNET	2	-	-	2
IRIA	1	-	-	1
TOTAL	26	1	1	29

Of this staff, six members hold Postes at the full or associate professor level: Gelenbe and M. Chabert, whose work is in systems; G. Guiho and M. Kaiser in artificial intelligence, or more particularly, automatic programming; J. Vueillmin, who is studying the nature of algorithms and, to some degree, also automatic programming; and M. Bermond, who holds a CNRS Poste and is concentrating on graphics and combinatorial logic.

Local Area Networks: Gelenbe became involved in satellite communication protocols in 1974, and his work in that field produced results that contributed to improved access control and system stability and to implementation technology which could be more broadly applied. Study of the problem of how to maximize throughout for a random access channel led him in 1976 to an interest in the application of this prior work to Local Area Networks (LANS) along lines suggested by R.M. Metcalfe in such articles as "ETHERNET: Distributed Packet Switching for Local Computer Networks," *Comm. Assoc. for Computing Machinery* 19, (July, 1976). With GIXI, Gelenbe designed and built a 3-station prototype system. The nodes are minicomputers (Digital Equipment Corp. PDP 11/03), and they access a fiber optic channel, providing a very powerful computing facility. GIXI is now expanding this into an LAN suitable for service to the entire University and would like to follow this with a commercial product line of campus networks. There seems to be a huge market for such a product. The target system would handle heterogeneous computers and would serve LRI as a test bed for work in distributed data bases and advanced telephone systems.

Distributed Data Bases: Gelenbe's team has been active in three major aspects of distributed data bases:

(1) Reliability and Recoverability—Effort in checkpointing has been under way since 1976, and the important paper by Gelenbe and Derochette entitled "Performance of Rollback Recovery Systems under Intermittent Failures" appeared in *Comm. Assoc. for Computing Machinery* in June 1978. Out of this and the performance evaluation work described below comes Gelenbe's finding that for efficient and effective performance, checkpoints must be established not at constant time intervals but at intervals of constant work performance. Thus, the checkpoint time interval should vary inversely with workload.

(2) Consistency—Gelenbe here is tackling problems of definition and evaluation; seeking good, quantitative measures for consistency and exploring methods for designing algorithms that do not depend on locking the entire data base or portions thereof from time to time. Thus he is examining performance of various methods of decentralized update control, trying to determine an optimum trade-off between coherence and promptness.

(3) Performance Evaluation—The current state-of-the-art requires large simulations which usually entail several man-years to develop. Gelenbe feels

that, using queueing network mathematical models, the system simulation can be reduced to work of a few man months at most.

Turning now to another subject, Guiho described the work being done at LRI in search of techniques for automatic generation of programs. He is really attacking a well known and very troublesome problem: Although the basic algorithms required to construct a system of application programs are readily available and often well known, the number of algorithms required usually becomes so large that the resulting system is inefficient of computer resources and unmanageable as a design product, so that it is usually impossible for the programmers to ensure the correctness of the system. But just those characteristics that make the design of such systems difficult for programmers—the huge number of basic elements and the great size of the generated programs—seem very suitable to machine manipulation and should be well within the capability of current computers.

Guiho and his associates are examining various logical approaches to program synthesis: synthesis from examples in which input and output are defined; synthesis from assertion in which input and function are defined first in a noncompilable language and then gradually transformed into a compilable program; and synthesis through enumeration, a highly theoretical exploration of what Guiho describes as impossibility theorems (which I take to mean theorems which are impossible to express today as programmable algorithms but which are nevertheless potentially useful). Guiho's team has succeeded in building a system that can synthesize programs to deal with most problems involved in table manipulation. They wish to build on this work to obtain a system capable of synthesizing file handling programs.

In summary, I found that the staff at LRI at the University of Paris-South is extremely capable, and that their work is important, both in terms of basic research and in terms of producing solutions to current problems. And as a final impression, I found that the French are not only prolific in terms of scientific output but also in the development of acronyms. Who knows, they may be generating acronyms at an even faster rate than the Americans. [George M. Sokol, Chief, Information Sciences Branch, United States Army Research and Standardization Group (Europe)]

ENERGY

FORGET THE HINDENBURG: HYDROGEN FUEL LOOKS GOOD

The search for the ideal energy source goes on! The requirements are simple: It should be inexhaustible, nonpolluting, provide the needed capacity, be safe and, of course, be cheap. Suggested possibilities include nuclear fusion, solar, geothermal, and wind energy, and more recently, direct use of the hydrogen produced most probably by decomposition of water by electrolysis. However, hydrogen is contrasted from the others by being a secondary energy system; primary energy must be available to produce the hydrogen. This important difference is often overlooked or ignored by the more avid proselytizers of the hydrogen club.

As with so many "fashionable" programs, supporters tend to band together periodically to detail progress, and to sustain their enthusiasm by mutual encouragement. The hydrogen people did just that at the recent 2nd World Hydrogen Energy Conference in Zurich, Switzerland, held under the auspices of an impressive array of organizations. (The first such meeting was held in Miami Beach, in 1976.) The Conference was presented by the International Association for Hydrogen Energy, was hosted by the Swiss Federal Institute for Reactor Research, Würenlingen, in cooperation with the Swiss Federal Institute of Technology, Zurich, and the Clean Energy Research Institute of the Univ. of Florida. Sponsors included the US Department of Energy and a host of Swiss companies.

Switzerland's interest in the subject illustrates the more general worldwide interest. The Swiss must import 80% of their power, primarily oil, obtaining the other 20% by maximum use of their hydroelectric capacity; they are thus anxious to establish a nonfossil fuel energy system. Hydrogen could be an important factor in this development. That the enthusiasm is shared was evidenced by the nearly 500 participants from 35 countries. The Conference was structured in a reasonable way; mornings were devoted to keynote or review papers, while in the afternoon five

parallel technical sessions allowed the audience of very diverse interests to hear papers in their specialty areas.

Let me try to set the usefulness of hydrogen as an energy source in proper perspective before I detail some of the presentations. The most important factor is that the future of hydrogen is as a secondary energy source, with excess or off-peak energy being used to produce hydrogen by electrolysis of water, gasification of coal, or other processes. Thus, it is not a universal panacea, particularly for countries with restricted primary energy sources. The exception is the direct production of hydrogen by thermo-nuclear fusion, but the success of this process is far from certain.

The presentations were wide ranging in subject and tone, from almost evangelical calls for a worldwide commitment to hydrogen energy under the auspices of the United Nations to detailed scientific examinations of the most feasible technical and economic means for the production and storage of hydrogen gas. A glaring omission was any serious attempt to assess the interaction of hydrogen with materials, particularly how these could affect long distance transmission as through pipelines. Only one session (out of 18) was devoted to materials problems. More seriously, only a handful of people were in attendance here, and these were the few materials experts present. The other participants chose instead to concern themselves with other, more general aspects that were being covered in parallel sessions. This is not an isolated occurrence; too many physicists, chemists, and "global thinkers" seem to believe that production is the critical factor, and the resulting hydrogen could be simply and efficiently transported using the existing natural-gas pipeline network. This optimistic view is not shared by a considerable number of materials people.

An area that did receive considerable attention was the means available for producing hydrogen efficiently and at realistic cost. The most obvious of these is the electrolysis of water to produce hydrogen and oxygen. The efficiency of this process depends in large part on the overvoltage of the cathodic and anodic reactions (i.e., the necessary potentials to discharge hydrogen and oxygen, respectively), as well as the resistance drop across the two electrodes, which must take into account the electrode materials, the solution, and bubbles of the gaseous products of the electrolysis process. Research groups from the Institute of Electrochemistry and Metallurgy, Univ. of Milan, Italy; The City University, London, UK; and the Centre d'Etudes Nucléaires de Grenoble, France, discussed the potential for new materials both for the electrodes, which should be highly catalytic in nature to improve the efficiency of hydrogen production, and for diaphragms to separate the cathodic and anodic departments. Many new materials have been developed or designed to meet the problems associated with the increasing temperature and pressure and high alkalinities necessary for the efficient use of large electrolyzer systems. Candidates that are now being evaluated include teflon bonded semiconducting oxides (e.g., $NiCo_2O_4$), sintered nickel, and asbestos separators.

The advantages of a thermochemical cycle rather than electrolysis was discussed by groups from the Los Alamos Scientific Laboratory, New Mexico; the National Chemical Laboratory for Industry, Japan; and a number of others. The claimed advantage of a higher efficiency and lower costs have spurred efforts to develop thermochemical processes for water decomposition. Suggested cycles include: sulfuric acid and iodine, iron-chlorine, and sulfur dioxide and iodine. In all of these proposed cycles and others, the efficiency is strongly dependent on the ease with which the gaseous hydrogen can be separated from gaseous products or reactant gases. The energy expenditure involved in this separation can be of paramount importance in cycle selection, and most of the presented papers focused on the problem.

Other proposed schemes presented included the use of heat energy provided from nuclear reactors and solar energy or coal gasification to produce hydrogen either directly or in conjunction with one of the processes previously discussed.

Another major topic area was storage of the hydrogen. The efficacy of methods in use and proposed other ones were reviewed by J.H. Kelly and R. Hagler (Jet Propulsion Laboratory, California). These range from the prosaic method of gaseous storage in high pressure tanks [up to 10,000 psig (70 MPa)] to the more sophisticated cryogenic and metal hydride storage schemes. While gaseous storage has the potential prob-

lem of embrittlement of the storage material, steel, the combination of limited time use of the vessels and serendipity has permitted long-term storage of this method to be carried out reasonably safely. The major problem is that very large storage capacity is needed because of hydrogen's low density.

Liquefaction of the hydrogen solves this latter problem, as pointed out by J.J. Thibault (L'Air Liquide, France). He presented data to support his claim that because of cheaper transportation costs, liquefied hydrogen can be competitive with gaseous hydrogen even when liquefaction costs are considered. The liquid is even more cost-effective when the hydrogen is to be used in its liquefied state, for example as a rocket fuel.

The most exotic storage scheme is the use of metal hydrides. These are attractive because of the extremely high density of hydrogen in these compounds, which exceeds the same volume of liquid hydrogen. For example, MgH_2 has a hydrogen storage capacity of more than 0.1 g/mliter of volume compared with 0.07 for liquid hydrogen. A number of papers considered the effectiveness of potential hydrides such as binary titanium alloys (O. de Pors and H.M. Lutz, Battelle Institute, Geneva, Switzerland) and ternary $LaNi_5$ intermetallic compounds (A. Percheron-Guegan and co-workers, Centre National de la Recherche Scientifique, Meridon, France). They and others considered the problems of reversibility, embrittlement, and cost, which are some of the limiting factors in the use of metal hydrides.

An interesting adjunct to the meeting was a small technical exhibit, with operational hydrogen-fueled vehicles produced by Mercedes-Benz of West Germany and Billings Energy Corp., Utah, being the highlight.

Those interested in further detailed information on the published proceedings or on specific technical or commercial aspects should contact the International Association for Hydrogen Energy through the Clean Energy Research Institute, Univ. of Miami, Coral Gables, FL. (I.M. Bernstein, Carnegie Mellon Univ., Pittsburgh, PA)

GETTING CHARGED UP IN THE UK: THE ARMY-NAVY-AIR FORCE GAME IN BATTERY RESEARCH: PART II - NAVY

Last month's issue of *ESN* included the first in a series of three notes on battery research in representative defense laboratories of the three UK services. That one (*ESN* 33:184) described programs at the Royal Armament R&D Establishment (RARDE), an Army lab, while this note considers battery research at the Admiralty Marine Technology Establishment (AMTE), Holton Heath. The final installment next month will review work at the Royal Aircraft Establishment (RAE), Farnborough.

AMTE-Navy: Battery research at AMTE is a section of the Chemical Technology Division. During a recent visit, the section head, Len Pearce, described work underway on a variety of systems mostly for naval ships and weapons applications. The program seems to be more concerned with basic cell technology than perhaps is the case at the other two laboratories and is more involved in primaries than secondaries. One of the major AMTE interests is with new cells that can be used in high-energy-density primary batteries to be discharged at high rates in weapon (e.g., torpedos) propulsion systems. The applications of these and other battery systems in more conventional electrical power applications, such as electric power load sharing and electric vehicles, is also being pursued to some extent; the section supplies advice to other UK government departments having interest in these applications. Two cell types of particular concern are the seawater-activated battery (for sonobuoys and emergency lighting) and the high temperature lithium-iron disulfide battery. As at the other MOD establishments, the AMTE program includes a significant contribution from extramural projects. This includes work at the Atomic Energy Research Establishment, Harwell; the Univ. of Newcastle upon Tyne; Imperial College of Science and Technology, London; and other sites.

Pearce reviewed the group's work on molten salt reserve batteries, often referred to as "thermal batteries," that are extensively used as power sources in defense applications. These are the choice because of their excellent environmental stability both prior to and during use, wide range of operating temperatures, long storage lives, and reliability. Historically, a number

of electrochemical cells have been utilized for different applications, with the most common system being Ca/LiCl-KCl, $CaCrO_4$/Fe. All thermal battery designs depend on the principle that the cell components are solid and inert in the inactive storage state; but when power is required, a barium chromate/zirconium or iron/potassium perchlorate heat source is activated by an electric match or percussion cup, the electrolyte (LiCl/KCl) is melted, and battery power is then available.

Pearce explained that the poor efficiency of calcium anodes in existing molten state primary batteries has been a major deterrent to extension of their operating life beyond a few minutes at high electrode current densities. Recently, development both of satisfactory techniques for immobilizing lithium and of more suitable cathodes has to a great extent overcome this problem. AMTE investigations on a lithium anode system using immobilized salt electrolytes have shown that it is capable of working over a wide range of power densities at high electrode efficiencies.

Research on the lithium-iron sulfide (or disulfide) couple is being emphasized at AMTE, because the high efficiency and stability of the iron sulfide cathode material make it an attractive candidate for high-rate, extended-duration thermal batteries. Work on high current density thermal batteries began about 8 years ago; initially lithium and sulfur were chosen as the anode and cathode materials, respectively. Because of difficulties in designing a simple cell, obtaining an efficient separator, and the limits on the temperature range of operation arising from the low boiling point of sulfur (440°C), FeS_2 was subsequently chosen as the cathode. Laboratory work in the last few years has led to a simple pile-type cell design that exhibits few side reactions and has a high current density/long duration capability. A Li/FeS_2 cell is used for primaries, Li-Al alloy/FeS_2 for secondaries.

As a result of the single cell development work a range of pyrotechnically activated batteries has been designed, built, and tested by Mine Safety Appliances, Ltd. (Glasgow, UK). Major features of the primary system are high rate capability, up to 1 A/cm^2, and high utilization, up to 80%, over a wide temperature range (400-700°C). Principally 10 A-min cm^{-2} cathodes were used in these experiments. With secondary cells, over 100 cycles have been obtained at 10-hr rate (25 mA cm^{-2}), with utilizations between 80 and 90%. The cells are capable of sustained discharge at 100 mA cm^{-2}. The energy density goal for the secondary system is 150 W-hr kg^{-1}, four times that of current lead-acid batteries, and a power density goal of 250 W kg^{-1}.

Facilities at AMTE include a battery test-rig capable of handling up to 35-kW batteries at seawater pressures up to 6 atm, and a large clean room for preparation of lithium battery electrodes. Tooling is available for building batteries up to 30 cm in diameter, and there are extensive facilities for assembling cells in argon-filled glove boxes. When working with lithium, the boxes are scavenged with liquid lithium to prevent attack of the battery active material. These boxes are large enough to hold the assembled secondary batteries and furnaces for cycling experiments.

In summary, the main emphasis of battery research at AMTE (Holton Heath) is on developing and proving new cell designs, with particular interest in pyrotechnically-activated thermal batteries. By working together with battery companies and with basic support from universities in extramural research programs, new cell concepts are developed and prototypes evaluated. Impressive facilities and expertise are evident and are reflected by the successes of the program. (Jeff Perkins)

FLUID MECHANICS

TURBULENCE STUDIES AT THE TECHNICAL UNIVERSITY OF EINDHOVEN

Studies in turbulent transport phenomena at the Technical University of Eindhoven fall within the program of Heat Transfer of the Division of Transport Physics of the Department of Technical Physics. The chair in Heat Transfer is held by Prof. D.A. DeVries, who is currently serving in the higher administrative councils of the University. Acting in his stead is Visiting Professor K. Krishnaprasad, who comes from the Mechanical Engineering Dept. of the Indian Institute of Science in Bangalore. The Division of Transport Physics also has programs in various aspects of fluid mechanics, such as gas dynamics

and shock waves, air acoustics, wind energy, and kinetic theory.

The regular program at the University consists of four years of study in course work along with two student projects, each entailing approximately 60 afternoons of activity in theory or experiment, and an additional fifth year spent entirely in research. At the end of this period the student emerges with what corresponds roughly to a Master's degree in the US. With sufficiently high academic ranking, a student may then qualify for an appointment as a PhD candidate, in which case he receives a job that is paid for by the University. The Division of Transport Physics thus has some 15 pre-fifth year students, 10 fifth-year research students, and 6 PhD students at any particular time.

The research underway in turbulence includes: a study of flow over sudden change in surface roughness in water and wind tunnels and the use of a turbulence closure scheme of Bradshaw to response of the flow to a stepwise change in surface roughness; the study of turbulent Prandtl numbers in boundary layers on a flat plate relating to a stepwise change in wall temperature; the development of a fast wet-bulb temperature sensor consisting of a sputtered platinum film on a glass substrate probe 50 μm in diameter and of a star-shaped cross section supplied with a moisture film so that it can measure fluctuations of moisture content in a flow and enable the interpretation of meteorological data to yield shear stress and momentum flux in the atmospheric boundary layer.

Of particular interest to me is the doctoral thesis work recently completed by Anton Beljaars on a model for turbulent exchange in boundary layers, in which he provides a kinematic description of turbulent bursting phenomena. In this model Beljaars chooses a coordinate system moving with the burst and assumes that a thin laminar boundary layer begins to develop immediately under the burst and meets the next burst that follows. In his analysis Beljaars assumes a spanwise perturbation, which he feels is of the Taylor-Goertler variety and which in moving fluid from a low speed region near the boundary causes a point of inflection in the local velocity profile. Though the streak lines of this ejection process may appear dramatic in flow visualization, the actual ejection velocities are low compared to the principal flow vector in the boundary layer. The shear stresses caused by the longitudinal vortices at the wall are small, but the shear stresses caused by the instability associated with the resulting point of inflection in the local velocity profile account for the major drag on the boundary. The model draws inspiration from the classic work of Kline and the more recent analysis of Londahl.

The laboratory of the Division contains some very fine equipment. One low turbulence wind tunnel with a test section 40 cm × 40 cm in cross section with a 2.5-m long boundary layer heated plate is being used in studies of the turbulent Prandtl-Schmidt number and turbulent shear stress. It has a maximum velocity of 16 m/sec and is equipped with crossed, hot-wire probes and automatic traversing. Another low turbulence wind tunnel with a contraction ratio of 1:40 has a test cross section of 80 cm × 100 cm, is 8 m in length, with maximum velocity of 20 m/sec. It is intended for studies of the atmospheric boundary layer over various surfaces and changes in surface roughness. A water channel 100 cm × 100 cm in cross section, a 8 m in length, has a rated velocity of 15 cm/sec and is intended to complement the previously described wind tunnel in atmospheric boundary layer studies, using hydrogen bubble flow visualization in connection with high speed motion picture films and hot film probes.

The facilities at Eindhoven are most impressive. The buildings are of contemporary style with exposed structural and functioning elements and are all interconnected by elevated, glass enclosed passages. Eindhoven is supposed to be the younger relation of Delft; however, it is developing very rapidly and will be interesting to watch: (Martin Lessen)

ONRL REPORTS

See the back of this issue for abstracts of current reports.

FLOW VISUALIZATION WITH DYE STREAMS

Recently, at the headquarters of the Office National d'Etudes et de Recherches Aérospatiales (ONERA), I had the opportunity to observe on-going studies involving flow visualization of complicated laminar and turbulent flows. A program of such flow visualization of incompressible flows has been developed over a 20-year period at the ONERA Chatillon Centre, near Paris, to a state where it is a most useful method of studying flows from the point of view of both obtaining valuable results and understanding in detail the complicated flow phenomena that are involved. During my visit, the Deputy Director of the Aerodynamics Research Division M. Maurice Sirieix, first introduced me to M. Henri Werlé who is the division head of the water tunnel flow visualization facility ONERA, and then proceeded to show films of remarkable visualization of various flows.

The techniques that were demonstrated with water as the flow medium included injected dye streams of various colors (marking out stream lines) and bubbles of hydrogen and detergent. Most favored were the use of small dye streams introduced into the flow fields. Curiously, the most successful dye streams consisted of colored milk. The hydrodynamic tunnel facility is so equipped with interchangeable test sections that maximum flow velocities of 100 cm/sec and maximum test-section cross sections of 22 × 22 cm are available. Clearly, the Reynolds numbers that are obtainable in this facility do not permit the proper reproduction of detailed boundary layer phenomena in prototype large-scale flows. However, in studying flows over delta wings, for instance, the roll-up of the trailing vortices and their bursting can be demonstrated very clearly. By using two different dyes, one at a strake leading edge and one on the main delta leading edge, the interaction of the strake trailing vortex with the main trailing vortex could be studied. The study of pure and modified delta-wing planforms constituted a considerable portion of the studies undertaken in the hydrodynamic tunnel. The planforms for the Concorde and Mirage, for instance, were studied extensively at angles of attack of up to 26°.

In the visualization of flows about various wing planforms, tiny streams of dye of various colors were introduced at a number of points along the leading edge of the wing. The spiralling of these streams about each other in the wake gave a beautiful picture of the trailing vortices from the wing and the effect of changes in wing planform on the flow about the wing; also the property of the trailing vortices in particular could be studied. At high angles of attack the phenomenon of vortex bursting was visualized, and the effect of changes in wing planform and mass injection into the core of the vortex could be observed. It was found, for instance, that mass injection into the vortex core in a direction colinear with the axis of the vortex served to inhibit the bursting phenomenon and to move the vortex into a more outboard position over the wing. Though bursting was inhibited, the subsequent decay of the vortex was greatly accelerated by what seemed to be a strong hydrodynamic instability of the combined vortex and jet. It was also observed that the lift of the delta wing was increased by mass injection into the vortex when the position of the vortex over the wing was moved outboard. Films of other studies that had been carried out in this same tunnel included jet-mixing, starting and fully developed wakes from various objects such as discs and cylinders, flows at jet engine intakes, flow separation from various air foils, and laminar flow separation with subsequent turbulent reattachment. Some of these studies involved flows about high-lift wing configurations.

In a neighboring hydrodynamic facility the flow fields about hovering and forward moving helicopter rotors were studied. Again, the dye-stream flow visualization techniques enabled one to observe the details of the wake from a previous blade interacting with the flow about an ensuing one. Thus in some instances the trailing vortex from a preceding helicopter blade tip was intersected by a following blade, giving a detailed flow picture of blade-slap. In similar manner flows about rotating low-speed cascades could be visualized.

From what I could observe, the equipment necessary for the visualization of flow speed incompressible flows is neither extensive nor expensive. It would seem ideal for use in university teaching laboratories. Based on my own experience, I have found while students in many universities in the US receive excellent training in theoretical fluid

mechanics, they do not receive enough stimulation of intuitive insight with respect to complicated fluid mechanical phenomena. It would seem that one of the best ways of developing this insight would be to have available a facility for flow visualization such as that which has been so beautifully developed and demonstrated at ONERA. (Martin Lessen)

MATERIAL SCIENCES

THE END OF AN ERA AT THE CAVENDISH

The Physics and Chemistry of Solids Department of the Cavendish Laboratory, Univ. of Cambridge, has for three decades been an internationally recognized center for research on the surface physical chemistry of solids.

It all began when Profs. Frank P. Bowden and David Tabor joined the staff of the Physics Department in 1945-46; both having come from the Tribophysics Division of the Commonwealth Science and Industry Research Organization in Melbourne, Australia. During the 1950s and 1960s, they conducted extensive studies on the wear, friction, adhesion, and lubrication of solids. The results of their work are contained in their books *Friction and Lubrication of Solids*, (Oxford Univ. Press), the first volume appearing in 1954 and the second in 1964. These texts are standard reference works for anyone working in the field of friction, lubrication and wear—known today as tribology (ONR-London Report, R-4-78). Bowden died in 1968, but the work has been continued by Tabor up to the present. He, however, is on the verge of mandatory retirement, and although the activities of this very energetic scientist are not likely to cease abruptly, it is clear that the elegant work on friction and wear in the style of Bowden and Tabor is coming to an end.

The changes now occurring at the Cavendish are only partly the result of Tabor's retirement, however, for they reflect a shift in emphasis in research on solid surfaces in general. The present emphasis is to examine the atomic structure of solid surfaces by using such surface analytical techniques as Auger spectroscopy (AS), photo electron spectroscopy (PES), and low energy electron diffraction (LEED). While these techniques can reveal a great deal about the structure and composition of solid surfaces, most experiments must be carried out in high vacuum. These methods cannot address the many fundamental questions that still exist about the wear, friction, lubrication, or adhesion of solids under normal atmospheric conditions. However, as Tabor pointed out to me in a recent visit, research on these problems is not fashionable. He finds that students are strongly attracted to the surface spectroscopics but are not keen on working on the more complex and less tractable "dirty" systems.

Tabor categorizes his work into "very clean" studies of gas interactions with solids and solid-solid interactions, and "less clean" studies on the cutting of metals. In the work on gas-solid interaction, Tabor and his associates are examining the structure of metal surfaces using LEED and AS and hope to include PES soon. They are especially interested in surface reactions at low coverage and the effect on reactivity of atomic steps on the surface. This work will ultimately relate to gas-phase catalysis.

The work on solid-solid interaction deals with the adhesion of metal surfaces in ultrahigh vacuum: specifically, with the effects of both physically and chemically adsorbed vapors on adhesion, and also the adhesion of metal alloys and the effect of minor constituents of the alloy diffusing to the surface. In a related study, Tabor and associates are investigating the adhesion of very sharp metal points to flat metal plates. Theory would have it that if the probe tip is sufficiently small (less than 50 Å in diameter) so as to be essentially dislocation free, it should exhibit exceptional hardness. They are not finding this to be the case.

In the machining of metals the cutting process is very complex and poorly understood. Tabor and his associates have been trying to understand the mechanisms involved and are currently studying the process in low oxygen environments to determine the effect of suppressed oxidation of the freshly cut surface. They are also examining the effect of various gases and liquids on cutting. They use a transparent sapphire cutting tool, so that they can look through the tool to observe

the cutting action in detail. They are trying to understand various aspects of the process, e.g., why so many metals cut better in the absence of oxygen and why there is so little transfer of metal to the front edge of the cutting tip. They are also interested in the flow dynamics of the lubricant at the cutting edge.

In the 1960s, Bowden began work on high-speed phenomena. Specifically, he investigated the explosion initiation and propagation in propellants and the impact of liquid drops on solid surfaces, i.e., rain erosion. To follow these and similar phenomena in detail, Bowden and his associates developed high-speed cinematography techniques. These studies are continuing at the Cavendish under Dr. J. E. Field. During my visit, he demonstrated the complete destruction of a glass disc by the impact of a 25-mm-diam. water drop propelled at 750 m/sec. At these high speeds the water drop behaves as a brittle solid and shatters the glass like a steel ball. Moreover, the outward flow of the drop immediately after impact imposes considerable shear forces that add to the damage.

In addition to the multiframe cameras developed by Bowden, Field and his associates have a laser-source synchronous drive camera which is triggered by the event rather than by an operator. Field's current interest is on elastomeric coatings that inhibit rain erosion of aircraft windshields, as well as the rain erosion of graphite and glass fiber composites.

In conclusion, it can be seen from the above that although the era of classical work on friction and wear may be coming to an end and the emphasis will probably change after Tabor's retirement, by the use of such up-to-date technologies as LEED and AS he, himself, has started a new chapter of work in his Department. (Willard D. Bascom)

WERKSTOFFKUNDE IN NIEDERSACHSEN (LOWER SAXONY)

(KEY WORDS: metal physics, strengthening, dislocations, diffusion, superconductivity, recrystallization and grain growth, electrochemistry, surface films, local corrosion, hydrogen effects, cavitation and erosion.)

Research in materials science (Werkstoffkunde) in the Lower Saxony province in northern Germany was recently surveyed in a trip that included visits to four university centers: Göttingen, Braunschweig, Clausthal-Zellerfeld, and Hannover (the provincial capital). An interesting aspect of this trip was that it offered an opportunity to examine the effects of recently legislated changes in university organization in this region. Provincial governments in Germany are able to legislate quite independently in such areas as higher education, and a significant new initiative was recently passed in Lower Saxony that, in addition to reorganizing the top-level administration, effectively abolishes the old patriarchal institute system at universities. In fact, the effects of this new law cannot be completely measured as yet. For further insight on this subject the reader is referred to the ONR London Report by R.T. Schneider [R-18-75, 3 December 1975: "The German University System" (A018-965)].

Georg-August-Universität zu Göttingen: At Göttingen, organization according to the "old" system persists, with the University divided into several separate faculties: Mathematics and Natural Science, Medicine, Philosophy, etc. Each of these is divided further into several areas ("Fachbereiche"). For example, within the Mathematics and Natural Science Faculty are Fachberiche for Mathematics, Physics, Chemistry, Geology, and Biology. Each Fachberiche is composed of several institutes. For example, the Fachbereich Physik at Göttingen has nine institutes, one of which is the Institut für Metallphysik headed by P. Haasen. Although the new law requires the abolishment of institutes in the classical "one-man" patriarchal style and the main structure for academic administration will become the faculties (departments), research institutes can still exist if they are constituted by a group of three professors acting as a board of directors. In the case of the Insitut für Metallphysik, there happen to be three professors associated already (P. Haasen, T. Hehenkamp, and H. Teichler), so no particular change is expected.

One of the main themes of research in Haasen's Institute is "hardening" in general, encompassing mechanical strengthening, magnetic hardening, and

hardening of superconductors. If particles of a second phase are dispersed by precipitation in the microstructure of an alloy, the stress required for plastic deformation increases, a larger coercive field is observed in a ferromagnet, and a type II superconductor is able to carry an increased electric current in a magnetic field. Haasen therefore espouses a unified viewpoint for the discussion of these three phenomena, whereby the resistance of a statistical array of obstacles (the precipitates) against the movement of a flexible carrier (dislocations, Bloch walls, and magnetic flux tubes respectively) causes a change in the properties of the material.

Dislocations in semiconductors have recently received particular attention by Haasen. In these materials it is established that dislocations can carry a certain line charge resulting from the occupation of localized electronic states by electrons or holes. The effect of such features on dislocation mobility has been considered analytically and studied in detail by various experiments. To obtain insight into the microscopic processes involved, the mobility of single dislocations in such materials as GaAs has been observed as a function of stress and temperature. An interesting "torsion-pulse-loading" apparatus to study dislocations is used. Pulse durations of 1-50 μsec and various stress levels are used to move dislocations at different temperatures, and the speed of motion is measured by etch pit studies. Haasen is also studying recrystallization in the high voltage electron microscope.

Another member of the Institut für Metallphysik, Herbert Freyhardt, is also director of the "Sonder-Forschungsbereich 126 Göttingen-Clausthal," an impressive regional laboratory sponsored by the Deutsche Forschungsgemeinschaft (DFG) for crystal growth and careful specimen preparation purposes. Göttingen has one other national laboratory, a computer-controlled laboratory for Hall effect measurements (H.-G. Brian). Freyhardt's primary research interests are flux pinning in type II superconductors, which ties in with the general ideas about "hardening" mentioned above. His work in this field is tied to the development in recent years of several new techniques to produce *in situ* filamentary composite materials. In these, a two-phase mixture is produced either by powder metallurgy, precipitation, or eutectic decomposition, and the material is subsequently deformed, as by extrusion or wire drawing, to yield a structure with an array of aligned discontinuous filaments embedded in a matrix of a different phase. *In situ* produced filamentary composite materials exhibit a wide variety of interesting effects in their mechanical, electrical, and magnetic behavior, as has been clearly demonstrated by Wasserman and coworkers at the Institute of Metal Physics of Clausthal (reported on later in this note), and recent work by several groups around the world has shown that Cu-Nb,Sn composites may possibly become an alternative to well-established but more expensive and deformation-sensitive multicore superconductors.

Freyhardt has therefore conducted extensive studies on the superconducting properties of *in situ* formed multifilamentary Cu-Nb,Sn composites produced by a powder metallurgical technique. The wires contain 10 wt% Nb in the form of discontinuous filaments in a Cu-1 wt% Sn matrix, produced by hot extrusion of a powder mixture and subsequent wire drawing. Formation of layers of the superconducting Nb,Sn compound on the surface of the Nb filaments is by a diffusion treatment after plating with Sn. The peculiarities of the origin of the resistanceless currents have been studied extensively. The use of powder metallurgy in the preparation process allows one to choose (without limitations of thermodynamical considerations or quenching facilities) the composition, particle size, and total quantity of material produced. These materials can achieve resistanceless current densities exceeding 10^5 A/cm^2 (at zero field and 4.2 K). The critical current density depends strongly on the deformation and annealing conditions to which the wires are subjected, and on the tin content. Another technique has also been studied for the production of superconducting composites, namely the use of rapid (roller) quenching (of Cu-40 wt% Nb alloy) from the melt and subsequently plating (with tin) and heat treating. In related work, Freyhardt has analyzed fluxoid-void interactions in type II superconductors from a theoretical view and with the aid of experimental data. Also, radiation-induced (void) flux-pinning in oxygen-doped niobium has been studied.

Prof. Th. Hehenkamp's primary interests are thermodynamics of solids, atomic mass transport under the influence of various external forces (electric fields, temperature gradients, chemical gradients, etc.) and the problem of vacancy formation in metals and alloys. These are very basic studies, conducted in very systematic and complete fashion, with the aim of delineating fundamental laws. Noble metal alloys are often used as model substances, since the effects being studied are pronounced in them and since they are historically well known in the literature. With coworker Dr. V. Schlett, vacancy formation is being studied in the laboratory by an arsenal of techniques: electrical resistivity, positron annihilation, specific heat, and thermal expansion (via lattice constant measurements). A separate laboratory building for isotope studies is among the facilities developed by this group.

Also in this Institute is a large effort in the application of a Göttingen-built atom probe (R. Wagner) to various problems of microstructural characterization of alloys. This has been applied to studies of heat treatment effects in spinodal alloys (e.g., Cu-4% Ti) and to segregation phenomena in metallic glasses.

Technische Universität Carolo Wilhelmina zu Braunschweig: At the Technical University of Braunschweig I had discussions with the heads of two institutes, Prof. F. Haessner, of the Institut für Werkstoffkunde und Herstellungsverfahren and Prof. J. Ruge of the Institut für Schweisstechnik und Werkstofftechnologie. These two complementary and cooperating institutes are both within the Faculty of Mechanical Engineering, which is the largest at Braunschweig, having about 25 institutes. Haessner's Institute has a variety of researches, and the fact that not all are of direct interest to the director reflects its fairly loose structute. The research areas include microstructure-mechanical properties studies (particularly as related to recrystallization, grain boundary migration, and texture), gases in metals, calorimetry, anelastic properties, and corrosion.

Haessner's main area of personal interest is the theoretical treatment of grain boundary migration in metals during recrystallization. A related area is that of texture and anisotropy of mechanical properties, in which recent experimental work has concentrated on delineation of properties of various hexagonal metals (zinc, magnesium, titanium). For example, work is underway to determine how the constants σ_o and k in the well-known Hall-Petch equation (which relates yield strength, σ_{ys}, and grain size, d, by the expression $\sigma_{ys} = \sigma_o + kd^{-\frac{1}{2}}$) are affected by texture.

Calorimetric measurements are being made of the stored energy released from deformed and annealed metals, which is complementary to the general study area of deformation and recrystallization in metals. Also, reaction heats of metals relative to phase diagram determinations are being measured; in connection with this, an apparatus is being prepared for the Space Lab, where the experiment can be carried out without problems owing to reaction of the molten metals with the container materials.

An emerging area of interest for Haessner's Institute is glassy metals, in which a particular problem that will receive attention in the future is the stability of magnetic properties at annealing temperatures lower than the crystallization temperature of the metallic glass. (For a review of the current scene in glassy metals, see *ESN* 32-10:326 or ONRL Report C-10-78.) Calorimetric studies of crystallization of the amorphous structure will also be made, and various institutes will cooperate in an examination of anelastic behavior of these materials, such as by neutron diffraction and other methods.

Dr. P. Wehr is doing some very clever work involving determination of microstructure-electrochemical properties relative to the corrosion behavior of various metals, particularly involving welds. Potential-distance profiles across welds are routinely developed, using a microprobe electrode, the technique having a resolution of about 0.1 mm. Although very dilute (low-conductivity) solutions must be used to obtain this resolution, the technique dramatically reveals the effect of microstructural/compositional variations on local electrochemical characteristics and pinpoints the source of microgalvanic behavior. In addition to applications to classical problems of local corrosion in welded joints, the technique can be used to detect potential differences caused by plastic deformation, grain size variations in nonuniformly deformed and recrystallized metals, and

similar problems. Also, in titanium alloy electron beam and plasma arc welds, hydrogen distribution profiles across the welds have been developed by chemical analytical methods; in this work uniform corrosion behavior is found, but there are variations in mechanical properties as a function of hydrogen content.

Wehr also has a neat setup to observe microscopically the progress of dissolution of surfaces *in situ*. The apparatus employs gently flowing electrolyte and close temperature and potential control and can be used for various purposes, such as to monitor the progress of metallographic etching of difficult specimens, to study the progress of attack on different phases in multi-phase microstructures, to observe corrosion cracking, etc. In some cases Wehr is using this technique as a microscopic counterpart of macro-etch tests for local corrosion susceptibility such as the widely used Huey and Strauss tests. In the future it is intended to extend the apparatus from its present magnification limit of about 300× by immersing the objective lens directly in the electrolyte.

Prof. G. Vibrans' main area of interest is gases in metals, especially the effect of hydrogen on steel storage vessels. The three aspects of (1) possible surface barriers to hydrogen entry, (2) internal segregation of hydrogen, such as the so-called "traps", and (3) equilibrium "internal" hydrogen versus "diffusing" hydrogen induced by charging are being considered in an attempt to rationalize the behavior of steels under various conditions of hydrogen exposure. One of the major difficulties that Vibrans cites in hydrogen-effect studies is knowing the actual amount of hydrogen in the material and how it is distributed, and his experiments are designed to delineate and measure the various separate sources, locations and effects of hydrogen. This is, of course, a very ambitious aim, but one that will have great value if achieved.

Technische Universität Clausthal: At the Technical University of Clausthal, located in Clausthal-Zellerfeld, high in the Harz Mountains, I visited three separate institutes: The Institut für Metallkunde und Metallphysik, headed by Prof. H.J. Bunge, the Lehrstuhl für Werkstoffkunde und Werkstofftechnik, headed by Prof. B.L. Mordike, and the Abteilung Korrosion und Korrosionsschutz, headed by Prof. K.E. Heusler. The names of these "institutes" are themselves a contradiction in terms and a reflection of the evolving structure of the university administration. The literal translations of Institut, Lehrstuhl, and Abteilung are institute, teaching, chair, and department, respectively. Yet at Clausthal all of these metals institutes are within the Fakultat für Bergbau, Hüttenwesen und Maschinenwesen. (The term Faculty is synonymous with Department in Germany.) This faculty includes about seven other materials-oriented institutes in its complement of about 30 institutes. (Such topics as theoretical metallurgy, welding, forming, electrometallurgy, etc., are covered by the various other groups.) Unfortunately, my visit was too brief to survey them all and possibly sort out how they manage to work together to cover the materials scene from the research and pedagogical standpoints.

Bunge took over the leadership of the Institute of Metal Physics upon the recent retirement of its eminent former head, Prof. G. Wasserman, who still maintains office space and influence in its direction. I learned that Bunge got to Clausthal the hard way, having been ransomed by the East Germans in 1975 after being arrested while trying to cross the border furtively in 1974. His main interest is texture development during deformation, where he has perfected the technique of texture analysis by the so-called "orientation distribution functions" (ODF) method. ODF refers simply to the frequency of occurence of crystallites (grains) of different orientations in space. Since many physical and mechanical properties of crystals are orientation-dependent, including Young's modulus, hardness, magnetic susceptibility, etc., the determination of ODF for polycrystalline materials is quite important in understanding variations in such properties caused by deformation and annealing treatments. In fact, many solid state processes such as plastic deformation, recrystallization, and phase transformation are also dependent on ODF, and it can be used as a sensitive indicator to give insight into these processes. Bunge's group has developed quite sophisticated analytical and computational techniques to obtain data on crystal orientations in real samples (via the diffraction method known as "pole-figure

inversion") and convert it to ODF diagrams. The complete texture description requires, of course, the determination of a three-dimensional distribution function. Among the different pole-figure inversion methods, the series expansion technique has proven most versatile and has been employed widely in texture determinations. Several systems of computer programs have been developed to implement the method, in connection with automatic texture goniometers for neutron or x-ray diffraction measurements.

The research area pursued most recently by Wasserman is also still active. This involves the production of composite materials by extensive deformation (such as by extrusion) of powder starting components. Such systems as $Cu\text{-}Al_2O_3$, $Al\text{-}Al_2O_3$, Cu-Fe, Cu-fiberglass, and Fe-fiberglass have been studied extensively. These materials have some interesting technological aspects because anomalously high increases in tensile strength and other mechanical properties can be produced. The effect of second-phase particles on texture formation has also been studied. Currently, work on superconducting filamentary composites is being carried on by G. Frommeyer at Clausthal, who cooperates in this with Freyhardt's group at Göttingen.

Mordike's "Chair of Materials Science and Technology" was created quite recently, in the aftermath of Wasserman's retirement, and its research activities can only be reported in terms of what is planned rather than what has been accomplished to date. A small group of people has been assembled so far, and they are just beginning to acquire the new equipment they need to begin work. The range of interests includes elastic constants of metals, metallic glasses, and creep. Interestingly, it was Mordike who in 1974 first used PM techniques to produce superconducting composites of the type now extensively studied by Freyhardt at Göttingen.

Heusler's Institute is exceptionally impressive in its array of sophisticated electrochemical and analytical apparatus. In addition to a vast array of fairly conventional equipment, the laboratory is packed with special items that are often quite elaborate purpose-built systems. This includes a 4-parameter ellipsometer (which Heusler calls an "ellipsoreflectometer") for studies of thin surface films, a quartz ultrabalance, an optical microscopic setup to study corroding surfaces *in situ* (up to about 300×), and a special apparatus for the study of the behavior of iron in liquid NH_3. In this last study area, H_2O is an inhibitor to failure of liquid NH_3 tanker trucks, apparently because of the promotion of film formation, which is one of the phenomena being studied.

Ellipsometry and differential reflection spectroscopy (DRS) are two methods currently employed to investigate the optical properties and thickness of thin films on metals. It is a great advantage of these optical methods that the films can be investigated *in situ*, i.e., while they are formed or removed during passivation or activation in a solution. Two optical qualities characterizing changes in amplitude and phase during reflection of light at the film-covered surface can be measured. However, there are still at least three unknown parameters: the thickness of the film and the real and imaginary parts of the complex refractive index (i.e., the refractive index and the extinction index). In order to avoid assumptions about these parameters derived from nonoptical experiments, additional optical qualities must be measured; Heusler makes measurements of thickness, and the two indices are derived from DRS measured at several analysis of incidence. This is the "ellipsoreflectometer" mentioned earlier.

Another problem being studied is the kinetics of pit nucleation in iron, using ring disc electrode and spectrophotochemical methods. The latter technique, not previously used on inorganic species, is based on monitoring changes in optical absorption at a given rotation speed. The kinetics of ionic dissolutions are also being studied, and the morphologies of dissolution surfaces, such as on iron, are being examined by scanning electron microscopy. High temperature gaseous oxidation is also being investigated for such metals as Nb, Ta, and Ti.

Universität Hannover: At the University of Hannover (recently elevated to full university rank from its former status as a technical university), the head of the Institut (B) für Werkstoffkunde, Prof. F. Erdmann-Jesnitzer, unfortunately was not available, but I had some very interesting discussions with one of the younger members, Dr. H. Louis. The Institute encompasses three

main areas of interest: welding, alloy development, and fluid flow effects on the deterioration of materials. The last of these is Louis' area, where the general theme of the work is labeled as "damage due to hydraulics," encompassing the corrosion modes usually called "erosion-corrosion" and "cavitation."

I was particularly impressed with the fine apparatus for the study of flow effects on corrosion, including several instrumented flow loops, rotating disc apparatus, and vibrating plate equipment. For example, the cavitation behavior of various metallic materials are studied in a special flow channel in which the conditions within the cavitation field can be closely controlled; these conditions are already well known in terms of solutions to the fluid dynamics equations. The specimen chamber consists of a channel with a rectangular cross section (about 3 × 4 cm) in which two cylinder-shaped barricades are placed in such a way as to narrow the cross section (to about 3 × 0.3 cm), leading to the release of a bubble-filled jet of fluid onto the specimen surface. Special importance is attached to the size, position, and surface finish of barricades and to the back pressure in the system, all of which affect the nature and intensity of the flow field that is produced. The specimen is also made the working electrode in a cell so that electrochemical measurements can be made. The analysis then consists of the comparison of mass-loss and electrochemical data, as well as detailed scanning electron microscopy (SEM) studies of surface damage (such as looking at the same spot on the surface after various intervals of exposure). Also, surface roughness measurements are made as another gauge of damage. The SEM studies have been conducted for many years, and special expertise has been developed in the interpretation of the kinds of surface damage observed. Some very interesting studies have been made of the effect of heat treatment of steels on their performance in cavitation-erosion conditions.

Louis is also studying a useful application of fluid flow erosion i.e., liquid jet machining. Using aluminum as a model material and ordinary tap water as the fluid, he is investigating the jet cutting phenonema with possible ultimate application to stone cutting.

Summary: Materials science and metal physics research is certainly proceeding at an impressive pace in this representative sector of the German university system, and the range and depth of fundamental studies is quite remarkable. I must admit that a week's tour of these universities did little to clarify for me how they are actually administered, and it is hard to predict how the aforementioned legislative reorganization of the universities will affect research. However, at this time the atmosphere for research at all these places seemed enviably favorable, and one can only hope that the results continue at such a high level of quality. (Jeff Perkins)

MEDICINE

REDISTRIBUTION OF PULMONARY BLOOD IN HEART FAILURE—CURRENT THOUGHTS FROM BRITAIN

It is just over twenty years since the first radiologic report of pulmonary vascular redistribution in the failing heart was published. In the ensuing two decades considerable experimental work has been carried out on both sides of the Atlantic in an attempt to prove the clinical observation experimentally. Several theories have been proposed over the years, but at this time controversy still exists as to the exact mechanism. Although many are familiar with this subject, a brief review of the history and the physiology involved follows.

In 1958 Simon made the radiographic observation that in patients with left ventricular heart failure or mitral stenosis there was redistribution of pulmonary blood flow from the lower to the upper lobes. As is often true with new fundamental observations, there was an initial resistance to its acceptance, as it was difficult for many to believe that this could have been overlooked for years. A mechanism for this physiological event was hypothesized by Simon in his initial paper. This hypothesis was accepted by some and rejected by others, but it instigated considerable experimental work in the US and Britain. It has directly and indirectly led to a much improved understanding of the underlining mechanisms that affect pulmonary blood flow under varying conditions of increased pressure.

In the erect human, pressure in the pulmonary vascular system is significantly greater in the lung base than in the apex. The adult lung measures approximately 30 cm from base to apex, and if the hilar artery is taken as the midpoint, mean systolic and diastolic arterial pressures are reduced by about 15 cm of water at the apex and increased by 15 cm at the base. There is a similar and proportional variation in the pressure in the pulmonary veins, since they all enter the left atrium at approximately the same level. As the left ventricle fails, pressure rises in the pulmonary veins and, because of gravity, a critical level of increased pressure is reached in the lower lobes before the upper lobes. Vascular constriction at the base occurs which in turn leads to the redistribution of blood flow to the upper lobes. Conditions other than left ventricular heart failure can also cause redistribution of pulmonary blood flow. Except for primary pulmonary disease, the most common of these is mitral stenosis. However, any lesion that causes an increase in pulmonary venous pressure can cause a redistribution of pulmonary blood flow. Simon initially hypothesized a reflex arterial spasm as the cause of the redistribution under conditions of increased venous pressure. It was this hypothesis and the intriguing question of the exact mechanism that led investigators to pursue the problem.

Several additional clinical observations helped clarify the issue. Those patients who gradually develop left ventricular heart failure or who have long standing mitral stenosis demonstrate a complex of radiologic findings that are indicative of the chronicity of the failure. Other than pulmonary vascular redistribution, these include changes in heart size and contour, edematous interstitial septa (Kerley's B lines), and sub-pleural collections of free fluid. In addition, an increase in size and number of pulmonary veins can often be seen. As pulmonary edema develops, the outlines of these vessels become obscured by the surrounding fluid in the interstitial space. However, in those patients who do not have mitral stenosis or chronic congestive heart failure and in whom acute failure develops, pulmonary vascular redistribution probably only rarely occurs.

One of the first groups of investigators who attempted to explain the mechanism involved in pulmonary vascular redistribution was John West et al. He and his co-workers working at that time in London employed radioactive xenon to measure the distribution of blood flow. They used an isolated dog lung in their experiments and found that when pulmonary venous pressure was raised in the dependent portion of the lung, the interstitial edema itself was responsible for compromising the smaller veins in the lower lobes. B.C. Ritchie and his co-workers, however, demonstrated that West's experiment resulted in redistribution of pulmonary blood flow only under conditions of low blood flow and a low cardiac driving pressure. While these conditions are no doubt in effect in severe heart failure, they do not account for redistribution of blood flow under the more chronic conditions noted above. A.L. Muir and his colleagues concluded from their experiments, also using radioactive xenon, that redistribution occurred only with the formation of considerable alveolar edema and that the change was actually correlated with an associated reduction in pulmonary volume rather than in the amount of edema fluid present. It was not until 1975 that G.D. Surette and his co-workers suggested that the redistribution of blood flow in chronic cases may be caused either by the development of interstitial fibrosis in the lower lobes or by an actual narrowing of the smaller arteries and arterioles by hypertensive vascular lesions.

The incidence of pulmonary vascular redistribution in patients with congestive heart failure has not been clearly determined. Two separate studies of patients admitted to coronary care units revealed 33% incidence in one and 76% in the other. The disparity in these figures is probably related to the different types of patients admitted to the coronary care units of the two institutions.

Much of the experimental work on the problem of pulmonary vascular redistribution and pulmonary blood flow in general has been done in the London area. The subject was recently discussed individually with several British scientists active in the field. Dr. J.M.B. Hughes, a consultant in the Department of Internal Medicine at the Hammersmith Hospital, has been interested in the problem of pulmonary blood flow and redistribution for more than a decade. In 1967 he published an article in *Lancet* with West and others, demonstrating that the normally increased blood flow to

the lung base is reversed if the lung is at residual volume. (The residual volume is the amount of air that remains after a full expiration.) They thought this phenomenon was a result of an increase in interstitial pressure on the lung parenchyma of the lower lobes under the conditions of reduced expansion, i.e., at residual volume. Hughes believes at this time that a reduced pulmonary volume due, for example, to severe interstitial fibrosis may indeed cause a redistribution of pulmonary blood flow to the upper lobes. However, it is certainly true that interstitial fibrosis is a rare cause of pulmonary vascular redistribution and almost certainly not involved in the two common causes, left ventricular heart failure and mitral stenosis. In Hughes' opinion the vascular redistribution in those two diseases is secondary to a lesion that develops in the pulmonary arterioles and possibly in the small arteries. Hughes elaborated by drawing an analogy to the new-born lung. In embryonic life high pulmonary arterial pressure necessitates a high resistance in the arterioles. At birth the normal closure of the ductus arteriosus drops the pressure in the pulmonary system. However, if the ductus does not close or if the infant has a significant intracardiac shunt, high pressure is maintained in the pulmonary vascular system. Under these conditions the resistance in the arterioles remains high and a permanent lesion develops, which leads to pulmonary arterial hypertension. Likewise in the adult who suffers from chronic mitral stenosis, from an obliterative pulmonary vascular disease, or from chronic left ventriclular heart failure increased venous pressure is transmitted through the capillary bed to the arterial side of the system. Under these circumstances the resistance increases and arteriolar narrowing and eventually pulmonary arterial hypertension develops. It is this arterial hypertension, according to Hughes, that occurs initially in the lower lobes, diminishes pulmonary blood flow, and forces redistribution of blood to the upper lobes that are under less pressure.

Dr. John Peter Lavender, a consultant radiologist at the Hammersmith Hospital, has been interested in the physiology of pulmonary blood flow as well as ventilation perfusion differences for more than 15 years. Much of his work has been with radioactive isotopes, which have played a large role in investigating the problems under discussion since West's original experiment. Lavender also believes that an arteriolar lesion eventually develops when under chronic conditions the venous pressure rises. Since as yet an unknown but definitive period of time is necessary to develop the arteriolar lesions, redistribution of pulmonary blood should be seen only in chronic congestive heart failure. The exception should be quite rare and would occur only if significant pulmonary edema develops and pulmonary volume and pulmonary blood flow are markedly reduced in the lower lobes. While not refuting West's original work completely, Lavender suggests that it would be the unusual case in which pulmonary arterial driving pressure and pulmonary arterial flow would be low enough to establish the conditions under which West demonstrated pulmonary vascular redistribution.

Dr. David Trapnell, Consultant Radiologist at the Westminister and Queen Mary Hospitals, does not agree entirely with the opinions expressed by Hughes and Lavender. While he does not deny that an arteriolar lesion develops under chronic conditions, he claims that redistribution occurs rather commonly in acute heart failure as well. To prove this radiographically, one must have a recent normal chest radiograph prior to the acute development of congestive failure or show that the process is reversible. Trapnell had no cases immediately available to prove his point but contends that he has seen redistribution of pulmonary blood revert to normal after treatment of the heart failure.

If the contention of Hughes and Lavender is correct and an arteriolar lesion is a necessary prerequisite for pulmonary vascular redistribution, then, of course, it could not be reversible. To this point no studies have shown that pulmonary vascular redistribution is a reversible condition even if the mitral stenosis or left ventricular heart failure is corrected. This observer has never seen pulmonary vascular redistribution revert to normal once it has been established.

In summary, there is a redistribution of pulmonary blood flow from the lower lobes to the upper lobes in otherwise normal lungs under the conditions of chronic left ventricular heart failure or chronic mitral stenosis. This

observation was originally noted by Simon in 1958 who proposed a vascular reflex mechanism. Further work (West et al.) suggested that interstitial pulmonary edema may be responsible for the phenomenon of redistribution. One current British point of view disagrees with West and agrees with Surette that an arteriolar lesion almost certainly develops under conditions of chronic increased pressure in the lower lung zones but not under conditions of acute failure unless cardiac driving pressure and flow are very low. A contending opinion believes that redistribution does occur under acute conditions because of venous compression by interstitial edema. The development of an arteriolar lesion in those patients who have succumbed with chronic left ventricular failure or mitral stenosis is well known and has been histologically well documented. The essential question of the original initiating mechanism, which may not be identical to the final pathological appearance, remains. In the case of pulmonary vascular redistribution, however, it would seem that a chronic increase in venous pressure leads directly to arteriolar hyperplasia, vascular constriction and redistribution. (Irwin M. Freundlich)

HYPOXIC PULMONARY VASOCONSTRICTION—A SEARCH FOR THE CAUSE

Under conditions of reduced oxygenation pulmonary arteries constrict. This is in contrast to the systemic arterial system that dilates under similar conditions. The cause of this phenomenon has never been explained.

Past attempts to find a chemical mediator of pulmonary vasoconstriction have been universally unsuccessful. In an article published in *Lancet* in March of 1978, E.K. Weir postulated quite another theory. The title of his article contains the essence of his hypothesis, "Does Normoxic Pulmonary Vasodilatation Rather than Hypoxic Vasoconstriction Account for the Pulmonary Pressor Response to Hypoxia?" Paraphrasing Weir, the question might be put, since a mediator of pulmonary pressor response to hypoxia has not been found despite the work of many investigators, could the reverse of the expected mechanism actually be in effect? Could the phenomenon be explained if the pulmonary vasodilatation present during normal oxygenation were maintained by a vasodilator substance? Such a substance could be the enzyme bradykinin. Reduced production or increased destruction of bradykinin during hypoxia, according to the theory, would allow pulmonary arterial smooth muscle to assert itself and vasoconstriction to occur.

It is well known that at birth after closure of the ductus arteriosus there is a rapid fall in pulmonary vascular resistance and pulmonary arterial pressure. This phenomenon is caused in part by a change in oxygen and carbon dioxide tensions rather than by the mechanical expansion of the lungs. The smooth muscle mass of the small pulmonary arteries diminishes considerably within two to three months after birth. This change does not occur in the systemic circulation. If an infant is hypoxic at birth, the pulmonary arterial smooth muscle mass does not diminish, pulmonary blood pressure does not fall, and pulmonary hypertension eventually develops.

Bradykinin which is formed in the blood and is present in alveolar macrophages is critically dependent on local oxygen tension. Minute doses will markedly reduce hypoxic pulmonary vasoconstriction. It has been proved that the same enzyme that inactivates bradykinin and causes vasoconstriction in the pulmonary vascular system also converts angiotensin I to angiotensin II and causes vasodilatation in the systemic circulation. A mechanism for the interaction between systemic vasoconstriction and pulmonary vasodilatation is thereby explained by the action of a single enzyme. It is also well known that hypoxia and hypercapnia cause pulmonary vasoconstriction by separate mechanisms. The level of carbon dioxide tension in the blood modifies the pH, and since carbon dioxide tension rises during hypoxic conditions, acidosis is invariably present. A combination of acidosis and hypoxia has a synergistic effect in producing pulmonary vasoconstriction. It theoretically follows therefore, that the level of the blood pH may modify the rate of bradykinin inactivation while the oxygen tension may govern the level of bradykinin production.

Zakheim and his colleagues experimenting on hypoxic rats for another purpose made an interesting observation. The enzyme inhibitor SQ20881 prevents both the conversion of angiotensin I

to angiotensin II and the inactivation of bradykinin. These investigators exposed two groups of rats to hypoxic conditions for 21 days. They noted that pulmonary hypertension developed only in the group not treated with SQ20881. Therefore, the absence of the enzyme inhibitor (SQ20881) probably permitted the enzymatic inactivation of bradykinin to proceed, and pulmonary vasoconstriction with subsequent hypertension developed.

The critical importance of determining the cause of pulmonary vasoconstriction under hypoxic conditions cannot be overestimated. If pulmonary arterial hypertension could be successfully treated, the development of cor pulmonale and subsequent right heart failure could be prevented or at least inhibited.

Hilary Stanbrook (Research associate, Hammersmith Hospital, London), Dr. David J. Allison (Consultant radiologist and physiologist, Hammersmith Hospital), and Dr. John Armstrong (Univ. of Utah—currently working at the Hammersmith Hospital), are using an elegant experimental canine model to search for a possible vasopressor or to confirm the theory postulated by Weir. These investigators are using the cardiac lobe of the right lung, which in the dog is readily accessible for experimental purposes. Catheters are placed by the femoral approach into the main pulmonary artery, the artery supplying the cardiac lobe and the vein draining that lobe. The animal is also intubated and the bronchus to the cardiac lobe sealed by a cuff in order to strictly control the level of air flow and therefore oxygenation to the lobe. The independent ventilation of the cardiac lobe permits alveolar hypoxia to be induced in a single lobe without causing systemic effects. Mean lobar blood flow, pulmonary arterial pressure, blood pressure, and heart rate are simultaneously recorded.

Test doses of bradykinin given in the lobar artery invariably produce lobar vasodilatation and a fall in systemic blood pressure. In six separate tests (three dogs) the induction of hypoxia reducing the lobar oxygen tension caused an increase in pulmonary vascular resistance to a measured level of 16-25%. An increase of only 3-18% however, was observed if bradykinin was infused during the hypoxic state. When these investigators infused the converting enzyme, CEI, which prevents inactivation of bradykinin and inhibits the conversion of angiotensin I to angiotensin II, a significant rise in mean lobar flow was produced. However, there was no significant difference between the increased pulmonary vascular resistance observed during hypoxia before and after the CEI infusion. Thus the investigation has shown that hypoxic vasoconstriction is not caused by the rapid breakdown of bradykinin but is reduced with its infusion during hypoxia. However, the amount required to achieve this effect is much greater than a physiological dose and evokes systemic changes.

Although this investigation has shown that there is no increase in bradykinin destruction during hypoxia, Weir's general hypothesis may still be correct. It is possible that hypoxia inhibits the production of bradykinin while having no effect on its destruction. Another possibility would be that an entirely different substance, possibly related to bradykinin and present during conditions of normal oxygenation, is destroyed under hypoxic conditions. Thus, while Weir's hypothesis under one set of circumstances has been disproved, the theory could still be correct. The investigating team in the Department of Radiology at the Hammersmith Hospital will continue their investigative efforts. A bioassay of bradykinin levels will be made in an attempt to determine whether hypoxic conditions prevent its production. In addition, other substances that could be responsible for normal vasodilatation will be sought. (Irwin M. Freundlich)

THE POTENTIAL OF SATURATION DIVING TECHNIQUES IN THE AIR (OXYGEN/NITROGEN) DIVING RANGE

Despite the transportation problems created by the "New Ice Age" which has gripped Britain all winter, this one-day seminar organized by The Diving Technology Committee of the Society for Underwater Technology at the Society's London headquarters on 21 February 1979 was attended by an international audience of 80 to 90 people. Six papers were given in the morning session and six in the afternoon. The entire program

was chaired by Commander S.A. Warner (Chief Diving Inspector, Department of Energy) with his usual efficiency and good humor.

It is now well known that saturation diving in the air diving range is feasible and may provide greater flexibility than bounce diving in selected applications, primarily by virtue of longer working periods underwater. The aim of this seminar was to provide a variety of views on the subject and stimulate discussion. The meeting was somewhat marred by the prevention of discussion of current commercially used techniques (at least in relation to decompression schedules) because of "commercial-in-confidence" considerations. In this author's opinion this was unfortunate because not only have there almost certainly been no major breakthroughs in this area that are exclusive to any one company, but also, as is too often the case, researchers in this field become limited to a very small data base on which to develop more efficient and safer procedures. Two or three presentations were excellent and informative; others were less so, some to a considerable degree.

Dr. H.V. Hemplemann of AMTE/PL (Admiralty Marine Technological Establishment/Physiological Laboratory, Alverstoke, Hants), while speaking about the physiological problems, indicated that there are no new obvious hazards associated with prolonged air saturation as deep as 18 m or oxygen-nitrogen excursions as deep as 50 to 60 m, but stated that there is a need for more long-term studies on possible homeostatic shifts, including energy, mineral, and water balance. As two specific examples, he cited recent findings under investigation at AMTE/PL of changes in carbonic anhydrase distribution within human red cells after air saturation at 15 m, as well as changes in red cell morphology and increased erythrocyte sedimentation rates during decompression from deep oxy-helium saturation diving. While he suggested that these findings might conceivably lead to a more objective method of measuring the adequacy of decompression, it was pointed out from the audience that we should be cautious, since the red cell changes have been demonstrated in both the presence and absence of clinical decompression sickness (a situation reminiscent of the use of ultrasonics, a technique that has not lived up to its hoped-for predictive usefulness in this disease).

Dr. T.R. Hennessy then described recent work on development of decompression schedules from shallow air saturation depths. Reviewing past shallow air and nitrox dives (again from a regrettably small data base), he suggested that the initial pull to the first stop is critical to the ultimate total time of decompression and to the avoidance of decompression sickness. If the first stop is too shallow, bubbles will be formed in the initial pull and the subsequent decompression will in essence be a therapeutic table, taking much longer than it would have had bubbles not been present. On the other hand, if the first stop is too deep, the driving force for offgassing during the initial pull will not be maximized and one will enter the tail end of the decompression with too much tissue gas, which will nucleate and again cause symptoms. At present Hennessey is attempting to find this critical first stop from a saturation depth of 15 m on air, and a few preliminary trials have had much shorter total decompression times than other investigators have been able to attain. However, there have been several cases of very late onset (i.e., 5 hours after surfacing) decompression sickness, so this technique of altering the first stop as well as the tail end of the decompression needs a lot more refinement, and work is continuing.

Additionally, Hennessy pointed out other decompression-related problems that will need solving before this type of diving can realize its full potential. For example, a typical shallow engineering operation might require saturation at 15 m with work at 30 m in several three-hour-on, three-hour-off cycles followed by an eight-hour sleep period (or alternatively one long eight-hour shift per man per day at the work depth). While the most commonly used NOAA (US National Oceanic and Atmospheric Administration) final decompression tables appear safe following single excursions, it may be that repetitive excursions will need a different final decompression. Also, it is not known with any confidence how long to wait after the final work period before initiating decompression.

I will point out here that other facilities may be looking at the limitations in the application of the NOAA tables, for Dr. R.W. Hamilton and D. Kenyon (Tarrytown, NY) have proposed in the past to extend the NOAA concepts to provide work capability for operations

requiring repetitive dives to work depths from air or nitrox residence pressures, where any or all of the following factors might vary: habitat depth, work depths, excursion intervals, and repetitive intervals. There is undoubtedly room for more than one approach to these problems, and obviously some basic experimental work (as that undertaken at AMTE/PL) needs to be completed before adequate guidance can be given.

J. Sear's (Admiralty Marine Technological Establishment/Experimental Diving Unit, Poole, Dorset) presentation dwelt largely on the different types of system approaches that are now in use or are conceivable for use in air/nitrox saturation diving. The advantages of a system that provides independence from surface conditions and thus a continuity of operation (i.e., submarine-, shore- or rig-supported habitats) could dominate the decision network of which system to use. Sear also discussed the various options in regard to power sources, life support, the gas plant, communications, and diver heating. The next paper, completing the morning session, given by Surgeon Vice-Admiral Sir John Rawlins (Medical Director-General, Royal Navy), was a historical review of a sampling of the experiments and projects that have been undertaken internationally, primarily during the 1960s and early 1970s, both to generate interest in and attempt to understand the problems of saturating divers on air or nitrox. American and French programs were emphasized, however information was also given on some less widely known Russian projects (such as the SPRUT and SADKO underwater laboratories).

The afternoon began with a four-speaker session on potential applications in the following fields: Archaeological/Scientific by Dr. N. Flemming (Institute of Oceanographic Sciences, Wormley, UK); Offshore Industrial by Mr. M. Hey (Comex Diving, Ltd., Marseilles, France); Civil Engineering Industrial by Mr. D. Shiers (Shiers Diving Contracts, Ltd, UK); and Biological by Dr. N.S. Matthers (Heriot-Watt University, Edinburgh, UK). Flemming gave a very interesting paper, presenting examples of existing projects in which saturation within normal air depths could have been applied to great advantage, as well as examples of future work which, in some cases at least, will only be accomplished if shallow saturation techniques can be used. Both he and Matthers presented arguments for the utilization of these techniques: the advantages of direct access to the work site, economics of saturation (versus using existing nonsaturation techniques involving hundreds of thousands of man-hours of work spread over months or years), continuity of observation (with attendant possibility of continual underwater sampling and data acquisition and a much higher probability of observing rare and/or improbable events), and the ability to monitor diurnal variables (i.e., cyclical feeding and behavior patterns, which can be invaluable in helping to establish viable fisheries for example).

From the civil engineering viewpoint, Shiers noted that if this industry is to benefit from the application of techniques that will allow a greater scope of diver-oriented underwater construction and engineering, it is first essential that the design engineer is aware of such techniques and then designs the "use system" with a view to utilizing them. It became obvious, however, that at present the civil engineering applications are relatively rare and "capital costing" will frequently not justify the use of air saturation. Put another way, if the job can be done (with safety) using several techniques, the cheaper method will always win out.

Hey gave what I considered to be one of the best and most realistic papers of the seminar, briefly covering Comex experience in air saturation work on three typical projects (structural repair, pipeline construction welding, and pipeline tie-in work). The presentation included practical advice (i.e., stick welding in air liberates dangerous gaseous fumes). A typical job required saturation in a 0.4 bar PO_2 nitrox enviroment at 26 m with eight-hour working excursions to 36 m. Particular reference was made to the problems of welding and grinding in air saturation conditions. Because of sparks and high oxygen concentrations, there is an increased risk of combustion. Humidity can also rise to uncomfortable levels. A minimal ventilation rate of 30 m^3 per man per hour was recommended under these conditions. Welding and grinding should not be undertaken in air at depths exceeding 30 m. Likewise, these operations should not be undertaken in an environment with greater than a 10%

oxygen concentration unless the following precautions are taken: (1) there must be a rapid exit route from the habitat for all occupants, (2) a fire watch including the use of closed-circuit television monitoring must be in operation continuously, (3) appropriate and operational fire extinguishers are to be present in the habitat, (4) self-contained breathing apparatus must be worn in some instances and immediately available at all times, and (5) nonflammable clothing must be worn at all times. While stating that the use of air can save in both gas and logistics costs, Hey went on to say that at the present time, owing to the many restrictions on their use, the number of offshore industrial operations utilizing shallow air saturation techniques are quite limited. It was interesting to note that the term "habitat" as used in the offshore diving industry does not refer to the type of residential accommodations that the word usually brings to mind. Rather, the "habitat" is simply an enclosed space within which divers can work and is usually one-of-a-kind, purpose-built for the required task and then discarded. One example was the structural job that consisted of replacing part of a riser that had suffered damage near the surface in the splash zone. After cutting out the damaged section, the riser was surrounded with a simple air "habitat" (in this case an umbrella-like structure, watertight at the top and open at the bottom) within which divers could carry out the weld. Another problem mentioned was the interference from tidal conditions often encountered at these shallow depths (pressure fluctuations which can, for example, affect the weld).

Dr. J. Holthaus (Institut für Anlagen Technik der Gesellschaft Kernenergieverwertung in Schiffbau und Schiffahrt, Geesthacht, FRG) gave a description of the techniques of shallow air or nitrox saturation in general and talked about the German Helgoland habitat and its projects in particular.

The final paper of the day, given by Prof. D.N. Walder (Univ. of Newcastle upon Tyne, UK), was concerned with the question of whether bone necrosis will be a problem in shallow air saturation. The latest figures collected and analyzed by the Newcatle workers were reviewed in relation to depth and duration of exposure, incidence of decompression sickness and age. There was some discussion of the decrease in the incidence of decompression sickness among compressed air workers since the "Blackpool" tables have been in use. Of interest to this meeting was the fact that, although the incidence has never risen above 1.5%, most of the cases have occurred from exposures longer than 5 hours. Walder concluded that bone necrosis may result from air saturation diving and that if we are to get a satisfactory answer, detailed records must be kept from the start of an increase in this type of diving, and all records must reflect the depth of the exposure, details of the decompression table used, and any incidence of decompression sickness. Annual x-rays are another necessity.

One came away from the meeting with the impression that there is a wide selection of factors which can significantly influence the financial decisions on the utilization of shallow air or nitrox saturation techniques. While it is all too easy to consider the attendant advantages and potential applications, the user has to consider the problems also. Shallow habitats, in general, still require a great deal of surface support. They are not necessarily "easy" to operate, and the advantages gained by long bottom times may in some cases be offset by such other factors as the need for more sophisticated and comfortable breathing appliances, higher power requirements, necessity of diver heating for prolonged periods, etc. As oxy-helium techniques are so widely used and available at this time (plus the fact that helium conservation systems seem to be gaining acceptance), it may be that air saturation is often not as attractive to industry as it might seem at first glance. A stronger case may well be made for the scientific applications, and there is expected to be a continuing need for further development of this technology.

In summary, this seminar was valuable as a first stage in reviewing the practical procedures of air and nitrox saturation diving, in pointing out some of the limitations both in current knowledge and future applications, and in describing part of the work now in progress in attempts to assess the physiological uncertainties as well as new dimensions in the economics and safety of this type of diving. Further seminars were promised as progress continues.

A final note on a related point that was discussed: There has been confusion over oxygen partial pressure limits, particularly in reference to the NOAA tables for the longer and deeper excursion times. The new edition of the *NOAA Diving Manual* (now in draft form) will evidently clear this up. In the meantime, should anyone have reason to need this information prior to its publication, that person might wish to contact the Manned Undersea Science and Technology Office (NOAA, 6010 Executive Building, Rockville, MD, USA 20852), rather than relying on word of mouth information that will surely be misinterpreted at some stage in its travels. (LCDR Robert F. Goad, MC, USN, Institute of Naval Medicine, Alverstoke, Gosport, UK)

PHYSICS

PLASMA PHYSICS AT THE ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE

The Plasma Physics Institute (PPI) was created in 1961 and began functioning in 1962 as a national institute associated with the National Science Foundation of the Swiss Confederation. In 1973 PPI was attached to the Ecole Polytechnique Fédérale de Lausanne (EPFL), where it has been ever since. At present, steps are being taken to associate the Institute with EURATOM. The director of the PPI since its founding has been Prof. E.S. Weibel, who is also in charge of a group involved in experimental studies of basic plasma physics. The professional staff of the PPI consists of 27 physicists, and altogether there are some 160 positions, including technicians, administrators, and the like. If the association of the Institute with EURATOM is ratified by the University, some 15 more positions will be added.

PPI utilizes the services of the EPFL including its computing facilities consisting of CDC 6500 and CDC 6400 computers that may be used singly or coupled to give roughly the capacity of a CDC 6600. The Institute is financed by the Swiss Confederation through the EPFL, the National Science Foundation, and EURATOM. Until 1978 the budget of PPI lay roughly between 5 and 6 million SFr; the new budget for 1979, however, has been increased to 8.6 million SFr.

The program of PPI was explained to me by Dr. F. Troyon, who received his PhD in Physics at the Univ. of Rochester during the 1950s. The theoretical part of the program under the direction of Troyon consists of both basic plasma-physics-oriented and fusion-oriented studies. Among the fundamental studies that involve the physics of plasmas are also the more basically oriented aspects of rf heating, solitons in plasmas, nonlinear wave interactions, electron beam heating and the resulting ion-acoustic and/or Langmuir turbulence, and the relationship of this turbulence to a quasilinear predictive theory involving marginal instability considerations. The fusion-oriented activities include magnetohydrodynamic (MHD) stability studies of importance to the Tokomak, configuration rf heating, whistler-mode type instabilities, solitons and associated instabilities, and runaway electron studies. There are also ongoing theoretical studies in laser fusion, particularly in the area of energy delivery profile optimization. The theory group consists of 8 scientists who in the course of their work utilize the lion's share of the computing available in the EPFL computing facility. All the computing codes used are finite element codes and are two-dimensional.

The experimental activities at PPI concern laser applications for diagnostic purposes, basic experimental plasma physics and confinement, and heating of plasmas as applied to the Tokomak. One laser activity involves a transversely excited atmospheric (TEA) CO_2 laser whose 9.6-μm line is used to pump a heavy water (D_2O) laser whose 55- and 66-μm lines are utilized. This equipment is intended to measure ion temperature in a plasma via Thompson scattering. The Doppler shift of the scattered radiation gives the ion motion and hence the ion temperatures. PPI also has a service facility for maintaining the diagnostic lasers. The laser diagnostics group is directed by Dr. Ph. Morgan.

In the basic experimental plasma physics program a field-free plasma is confined at low density in various plasma boxes, utilizing multiple magnetic fields around the periphery of the boxes. These experiments are designed to check basic plasma-physics-oriented theory.

The Confinement and Heating group under the direction of Dr. F. Hofman of PPI is in the process of constructing a Tokomak. The design toroidal field

of this equipment is planned at 15 kG, the toroidal confinement geometry has an aspect ratio of 3 (ratio of major to minor radii of the torus, with the major radius of the torus equal to 60 cm). There is also the provision of field shaping of the Tokomak to yield an elliptical cross section having ratio of major to minor cross section diameters of 2 to 1 of the confinement torus. One purpose of the equipment is to study Alfven wave heating in which the disturbance wavelength is longer than the scale of the device.

A number of courses of instruction in Plasma Physics, Fusion, and Plasma Diagnostics, are offered to graduate students at PPI. Such students may obtain the Doctorate through the Physics Department at the EPFL.

The PPI seemed like a beehive of activity. The many foreign visitors that were either in residence or passing through during my visit seemed to attest to the high quality of the program. (Martin Lessen)

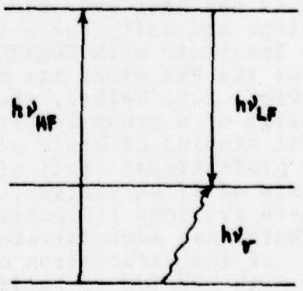
TUNABLE LASER SPECTROSCOPY

This is a report on a two-day workshop that immediately followed the April 1979 Atomic and Molecular Physics Conference in Liverpool. The workshop, which was sponsored by the Institute of Physics, was divided into three consecutively held sessions, with sessions I and II comprising invited talks from spectroscopists and laser specialists, respectively. Each presentation was in the form of an overview of a major subdivison of spectroscopy or laser development. The third session was an informal, but well-organized discussion with the objective of increasing the laser user/developer dialogue. I participated in this workshop, and my observations on each of these sessions follow.

The workshop organizers felt that previous meetings between laser users and laser developers have been somewhat dominated by the developers, in that they have spoken first and most. Hence the decision was made to have the spectroscopists present the first group of talks.

Professor W.J. Jones (Edward Davies Chemical Laboratories, Univ. College of Wales, Aberystwyth, UK) spoke on the applications of continuous-wave (cw) dye lasers in visible wavelength spectroscopy. Even though the visible portion of the spectrum (defined by Jones as 400 to 750 nm) is not a rich region for molecular absorption spectroscopy, the high power density output of cw lasers has been used in a number of ways to provide new data, e.g., for detecting very low fractional absorption by means of the optoacoustic effect, and in Raman absorption spectroscopy. The optoacoustic method of spectroscopy, sometimes referred to as photoacoustic spectroscopy, involves the detection of acoustic energy that is generated in a medium upon absorbing audio frequency modulated radiation. Vast improvements in this technique have been realized as a result of the laser's being used as the radiation source [V.S. Letokhov, *Opt. and Laser Tech.* 9, 263 (1977)]. Researchers using optoacoustic spectroscopy have demonstrated the ability to detect selected molecules with concentrations well below one part per billion [K.P. Koch and W. Lahmann, *Appl. Phys. Lett.* 32, 289 (1979)].

The role of tunable cw dye lasers in Raman absorption spectroscopy can be visualized with the aid of the following energy level diagram. The energy $h\nu_{HF}$ is provided by a modulated dye laser and that of $h\nu_{LF}$ by a cw gas laser, and the



condition for resonance is given by $\nu\alpha = \nu_{HF} - \nu_{LF}$. A modulation appears on the cw gas laser beam when the dye laser coincides with a resonance in the material under study. High resolution Raman spectroscopic data have been obtained for CO_3^{2-} in single crystal calcite using rhodamine 6G dye/HeNe lasers. A resolution of 0.0008 cm^{-1} was obtained for methane spectra by using rhodamine 6G and the 488-nm line of an argon ion laser.

The use of pulsed lasers in the study of solution reaction kinetics was briefly

presented by J.T. Richards (Department of Chemistry, Univ. of Salford, UK). He is studying the respiratory heme proteins hemoglobin and myoglobin that have the property of undergoing a reversible reaction with molecular oxygen. Even though these proteins have been studied extensively by many investigators, the complete mechanism of the cooperative binding of ligands such as O_2 and CO is not fully understood. However, flash photolysis experiments using flash lamps and more recently lasers have provided much information on the behavior of O_2 and CO complexes. Recently, photolysis experiments have been carried out using the following lasers: a) 615 nm from a passively mode locked dye laser (5×10^{-9} J/pulse); b) 530 nm from a mode locked frequency doubled Nd^{3+} laser (5 to 30 mJ/pulse); and c) 347 nm from a frequency-doubled ruby laser (300 mJ/pulse). After presenting a review of the results of some of these experiments, Richards made a plea for the development of a laser having the following characteristics: a) wavelength tunable from 700 to 1000 nm; b) repetition rate selectable from dc to 10^4 pulses/sec.; c) pulse width variable from 1 psec to 1 nsec; and d) the laser to be student and student-supervisor proof. After his presentation, Richards was asked by one of the laser specialists how much he would be willing to pay for such a laser. "£200,000" ($400,000) was his reply.

E.G. Wilson (Physics Department, Queen Mary College, London) reported on the application of a tunable dye laser to the investigation of electron and hole excitations in photoconducting polymers (one of the polydiacetylenes). Among the properties studied were the spectral dependence of excitation, carrier mobility (both along and perpendicular to the chains), and the time evolution of photocurrents. These polymers behave as semiconductors with a bandgap close to 2 eV, and a mobility ratio of 10^3 was observed for the two principal directions (parallel/perpendicular to the length of the chains).

The understanding of nuclear sizes and shapes and the testing of current theories on nucleus/electron interaction are of interest to G.R. Isaak (Department of Physics, Univ. of Birmingham, UK). He reported on optical heterodyne spectroscopic measurements of the optical isotope shifts in samarium and the hyperfine structure of sodium. Two US-manufactured argon-ion-laser-pumped tunable dye lasers were locked to different hyperfine structure or isotope-shifted transitions of atoms in an atomic beam and the beat frequency between the lasers was measured. As the atomic beam was very well collimated and as the lasers' outputs intersected the atomic beam at right angles, the Doppler contribution to the optical linewidth was far less than the 4-6 MHz laser linewidth. The precision of their optical transition frequency determination for the isotope shifts was ±200 kHz and that of the hyperfine structure work was ±20 kHz. Currently accepted theory cannot explain the two anomalous transitions that were observed in the isotope shift measurements [J.A.R. Griffith et al., *J. Phys. B: Atom. Molec. Phys.* 12, L1 (1979)].

I.W.M. Smith (Department of Physical Chemistry, Univ. of Cambridge, UK), has used a variety of tunable sources to obtain accurate quantitative information about vibrational energy transfer in molecular collisions. Infrared fluorescence induced by tunable lasers has been examined to understand better the energy transfer process. For example, frequency doubled tunable dye laser excitation of OH has provided information of the kinetics of selected excited states of this molecule. Smith expressed the desire to combine a cw laser as a probe to be used in conjunction with the already developed pulsed excitation lasers.

Four of the five speakers who were invited to present recent laser research and development efforts were from UK universities; the sixth was from Spectra Physics Inc., a US manufacturer of gas and dye lasers. The first speaker, L. Austin (Spectra-Physics Inc., Mountain View, CA), described their traveling wave ring resonator cw dye laser and presented some recent tuning range data on the dyes oxazine 1 and stilbene 3 when used in this laser configuration. The dye for all of the Spectra Physics work described was flowing in the form of a vertical jet. Linear lasers (lasers having a two-reflector resonator) have regions of unused gain owing to the standing wave pattern within such resonators. A more efficient use of the excited laser medium can be realized by using one of the many forms of the traveling wave ring laser (TWRL) resonator [W. Hugger, *Appl. Phys.* 15, 157 (1978)]. Unless a unidirectional de-

vice is incorporated within the TWRL resonator, two counter-propagating traveling waves will be present, hence the laser will have two output beams. Austin reported that for an argon ion laser pump power of 4 W, a single beam output power for the dye rhodamine 6G of 950 mW was observed when a unidirectional device was used. This was contrasted to the total two-beam output of 500 mW when the same laser was operated without the unidirectional device. An explanation for the increase in power was not offered. For rhodamine 6G, an almost linear relationship between pump power and dye output power was observed for pump powers up to 10 W, at which point the dye output power was 2.5 W. Using a krypton laser pump power of 4 W, it was possible to tune oxazine 1 from 695 to 784 nm. Nonoptimized mirrors were used for this experiment, and it can be expected that an increased tuning range will result from mirror optimization. Without saying more about the pump laser than giving its output power of 2.5 W, Austin reported a tuning range of 428 to 470 nm for stilbene 3.

The design and output characteristics of a frequency-doubled, ring resonator dye laser were presented by M.H. Dunn (Department of Physics, Univ. of St. Andrews, Scotland). The frequency doubling occurs in a crystal of ammonium dihydrogen arsenate, ADA, which was incorporated into an arm of the ring laser. With the aid of a computer, the lengths of the dye jet focusing cavity and the frequency-doubling cavity were optimized to provide for independent adjustment of both cavities. The length of the doubling crystal was also optimized to prevent intracavity aberations. A single output beam resulted from the use of an intracavity unidirectional device, and tuning was accomplished by a servo-controlled etalon, with the laser frequency locked to an external cavity. The following output characteristics were obtained with the use of rhodamine 6G as the dye laser medium and an ADA frequency-doubling crystal: a) ±20-MHz jitter, b) 3-mW output power, c) continuously tunable over 30 GHz, and d) scanning band can be set anywhere in the range 292 to 302 nm.

Ultraviolet laser radiation at megawatt power levels has become a reality with the advent of rare gas halide lasers (often called excimer lasers). C.E. Webb (The Clarendon Laboratory, Oxford) reported on laser tuning efforts, with an emphasis on the very recent Oxford results. KrF and ArF lasers operate on transitions from bound upper levels to lower levels that are repulsive. The spectra of the KrF and ArF excimer lasers is distributed over a broad structureless band approximately 2 nm wide. In contrast, the XeF and XeCl laser lower transitions are weakly bound, and laser emission from these excimers is comprised of several bands each having a width of a few tenths of a nanometer. At the Univ. of California Los Alamos Scientific Laboratory, two intracavity prisms had provided the dispersion for tuning a KrF laser, and a laser linewidth of about 0.1 nm was realized over the wavelength range of 192 to 195 nm. During March of this year, the Oxford group observed a high degree of selectability between the three emission lines (between 307.6 and 308.5 nm) of the XeCl laser. This was accomplished by using a 1200 line/mm grating as the intracavity tuning element. Webb reported that in April they set the grating at a grazing angle, thus increasing the number of lines illuminated by the laser. As the resolution of a grating is proportional to the number of lines illuminated and as the resolution of the intracavity dispersive element determines the linewidth of the laser emission, a much narrowed emission was observed. The laser could be tuned over the entire XeCl band with an instrument-limited linewidth of less than 0.01 nm. A higher resolution instrument will have to be used to determine the true linewidth in the near future. Webb feels that excimer laser tuning advances, coupled with laser emission shifting techniques, will provide for laser radiation at megawatt power levels over much of the 180 to 500 nm spectral region.

Tunable noble gas excimer lasers operating in the vacuum ultraviolet portion of the spectrum were reported on by M.H.R. Hutchinson (Department of Physics, Imperial College of Science and Technology, London). This type of laser is operated with the gas (xenon or argon) at high pressure (up to 25 atm) and is excited with relativistic electrons. The following table presents the output characteristics of a xenon laser, tuned and untuned. Tuning was accomplished with a prism/etalon combination, and the repetition rate in

either mode was 1 Hz.

	Untuned	Tuned
Gas Pressure	7 - 10 ktorr	7 - 10 ktorr
Pulse Energy	15 - 55 mJ	2 - 20 mJ
Pulse Duration	3 - 16 nsec	3 - 16 nsec
Peak Power	5 MW	1 MW
Tuning Range	-----	170 - 175 nm
Linewidth	1 nm	0.15 nm

Preliminary results were presented on the development of a tunable argon laser. This laser's untuned linewidth was 2 nm, centered at 126 nm. Owing to the high absorption of optical materials at this wavelength, prisms cannot be employed to tune the argon laser. A grating will be used as the tuning element in upcoming tuning studies at Imperial College, and both linewidth and tuning range data will be available in the near future.

There are no less than ten approaches to generating tunable laser radiation in the near (0.8-3 μm) and medium (3-30 μm) infrared. R.C. Smith (Department of Electronics, Univ. of Southampton, UK) spoke on three near and medium tunable source techniques that he feels have made the successful transfer from the developers' to the users' laboratories. A general overview of the capabilities of the color center laser was presented. Color center physics and the design of tunable color center lasers will not be discussed here except to say that color centers exist in crystals that have imperfection-trapped electrons and that color center lasers are optically excited. [Excellent reviews of tunable color center lasers can be found in: L.F. Mollenauer and D.H. Olson, *J. Appl. Phys.* 46, 3109 (1975); and G. Litfin and R. Bergang, *J. Phys. E. (GB)* 11, 894 (1978).] Color center lasers can be tuned from 0.8 μm to 3.3 μm and can be operated either pulsed (with powers up to 100 kW) or cw (up to 1 W), and very short pulses (down to 4 psec) have been obtained from a mode-locked color center laser. The tunable outputs available from the down conversion of dye lasers and optical parametric oscillators, as summarized by Smith, follow.

Down Converter Material	Tuning Range (μm)
$LiNbO_3$	0.35 - 4.5
$LiIO_3$	0.3 - 5.5
GaSe	0.65 - 19
CdSe	0.75 - 25

The following tuning ranges have been observed with $LiNbO_3$ used as an optical parametric oscillator.

Excitation Source	Tuning Range (μm)
Freq.-doubled Nd^{3+} (0.53 μm)	0.55 - 3.7
Rhodamine 6G Dye laser	0.8 - 2.6
Nd^{3+} (1.06 μm)	1.45 - 4

R.C. Smith, the current chairman of the Quantum Electronics Group of the Institute of Physics, organized the discussion section of the workshop. To facilitate the dialogue, he divided the spectrum from the vacuum ultraviolet to the far infrared into six "bands" and a list of tunable sources for each "band" was produced. At this point, general observations and problem areas were elicited from the laser users. There was agreement by those working in the medium infrared that their sources were too complex and that the cost of some replacement components was too high, e.g., laser diodes. Those working in the visible were bothered by vibrations introduced by laser cooling systems, microbubbles in circulating dye solutions, lengthy time delays in the delivery of replacement argon ion laser tubes, lack of sufficiently long intracavity experimental volume, and the high wear rate of dye jet nozzles. (After the discussion of argon ion laser problems, one of the workshop participants volunteered that it is anticipated that an argon laser will become available in the UK by June or July of this year. The laser will be produced by Barr & Stroud Ltd. and will have an output power between 4 and 5 W.)

Based on comments by the workshop participants during and after the last section, and my own observations, I feel that this workshop was of considerable benefit to both the laser users and laser producers. (Richard S. Hughes)

OPERATIONS RESEARCH

OPERATIONAL RESEARCH IN THE UK MINISTRY OF DEFENCE

To describe the total operational research effort in the UK Ministry of Defence would be almost as difficult as to describe the corresponding operations research effort in the US Department of Defense. This article discusses the central organizations doing such analyses.

We begin with Whitehall. Whitehall is actually the name of a London street (off which runs Downing Street, where the Prime Minister lives); but since a number of government offices, including the Ministry of Defence and the headquarters of the three services, are located on this street, "Whitehall" in the context of this report corresponds to "Pentagon." At Whitehall there are analytic groups for each of the three services.

Much of the analytic work and most of the R&D for MOD is done at the "Establishments," of which there are about a dozen. Some of these are identified primarily with one of the services (e.g., Admirality Underwater Weapons Establishment) and some with particular weapons (e.g., Atomic Weapons Establishment). Many of them have Systems Assessment Groups; one of these, at the Royal Aircraft Establishment, was mentioned in *ESN* 33-4:133.

A rather interesting one, the Royal Signals and Radar Establishment (RSRE), has been treated a number of times in this publication. (See *ESN* 32-8:283; 32-10:344; 32-11:391.) It is divided into two more or less equal parts, one of which is "Systems," the other "Applied Physics." The Deputy Director for Systems, Dr. T.P. McLean, is an elementary-particle physicist. RSRE is in Malvern, Worcestershire, about 100 miles west of London. It was formed by the consolidation of three establishments: the Royal Radar Establishment, the Signals Research and Development Establishment, and the Services Electronics Research Laboratory. The consolidation is not yet completed, and much building is still underway at Malvern. RSRE supports all of MOD in electronics, and also has responsibility for the development of specific systems in radar and communications, as well as technology development. Unlike the other MOD Establishments, work done at RSRE is also supported by nonmilitary government organizations. In particular, almost 30 people here are working on Air Traffic Control, supported by the CAA, which, in turn, is supported by the fees it charges rather than by the taxpayers. RSRE is working on equipment development, computer assistance for air traffic controllers, and other aspects of ATC for which they have a capability which is lacking at CAA.

All but one of these R&D Establishments reports to the Procurement Executive of Defence. The exception is the Defence Operational Analysis Establishment (DOAE) in West Byfleet, Surrey, some twenty miles southwest of London. DOAE, which reports to the Chief Scientific Advisor in the Defence Council of MOD, is described in some detail in this article.

At Whitehall, each of the three services has a Chief Scientist who wears two hats: on the one hand, he runs one or more of the R&D Establishments, and under this hat he works in the Procurement Executive. On the other hand, he supervises a number of local activities in Whitehall, including the analytical groups; under this hat he works for Operations. Thus, in the Air Force, under the Chief Scientist is a Deputy Chief Scientist, and reporting to him are three Assistant Chief Scientists, one for New Weapons Systems, another for Training, and the third for Logistics. I talked to David Faddy, the Assistant Chief Scientist for Logistics, who has the smallest of the three groups, namely eight people, doing OR studies. I also talked to his opposite number in the Navy, M.T. Murray, Assistant Director in the Directorate of Naval Operations (DNOS), and to his boss, the DNOS himself, T.H. Pratt. About one third of the total effort of this Directorate is devoted to OR.

These groups concentrate on applied OR, and, in fact, reject theoretical work to a significant degree. There are few doctorates among the staff, few academic connections, and almost no publication of scholarly work. They almost never utilize university students doing their practicum, in contrast to industrial OR groups, which usually support a number of students doing their projects for the MSc in OR (*ESN* 32-12:427).

They feel that it takes too much time to supervise such students. They feel that an OR project should yield an unambiguous recommendation, and academics tend to equivocate. And they may feel that dealing with universities complicates the maintenance of security. For these and other reasons, tney contract out a moderate fraction of their work. Such contracts almost invariably go to profit-making organizations, in contrast to the US, where such contracts frequently go to universities or not-for-profit research institutes.

At DOAE the attitude is somewhat different, largely because of the influence of one man, Ken Bowen, who has the title Head of Research. He is one of three men in the establishment who holds the rank of Deputy Chief Scientific Officer, which corresponds very roughly to GS-16 or GS-17 in our Civil Service system. This rank is also held by the two Deputy Chiefs of the Establishment. Bowen is very active professionally in operational research and publishes prodigiously. He sponsors research at universities and encourages university-related research. DOAE encourages analysts in the Establishment to undertake graduate work. In spite of all this, only 12 of the 66 civilian analysts have doctorates (mostly not in OR) and only 6 others have the MSc in OR. Only 12 are members of the OR Society (with Bowen, of course, being one of them). "Our people consider themselves defense analysts rather than operational researchers" I was told by a Deputy Chief of DOAE.

A typical problem in Faddy's Air Force logistics group concerns the number of spare engines needed, and their locations. This is a recurring problem with which the military constantly wrestle (see, for example, *ESN* 33-2:77). It has long been known that there is a cyclic requirement, because, for example, all of the aircraft in a squadron will have 100 operating hours per year, and therefore 5 years after a squadron has been supplied with aircraft (presumably all new, and all delivered at about the same time) they will all come up needing 500-hour checks at about the same time. Thus the number of engines under repair for a particular aircraft type in a particular aircraft squadron tends to look like a sinusoid. There is considerable blurring of this sine wave owing to "noise," and it tends to damp out, but the life of the weapons system is likely to be only a couple of cycles.

The outlines of this have been known, but the details, including the amount of blurring and damping, were not known. The technique used here was a detailed simulation of the aeroengine support system, including removal of engines, decision to repair or send back to a rear echelon, details of scheduled maintenance, and the like. There were several studies, using a total of 8 hours on a large machine (ICL 1905S) for numerous iterations of 15-year history. "Savings in reserve engine requirements over the next 10 years achieved through the use of [these] models are conservatively estimated at over £15M."

Murray's group in the Navy has a very similar problem, but they cannot use one another's models because everything is very specific; differences such as maintenance on vessels rather than at airfields make the studies incompatible. So the Navy group built its own simulation to determine the number of spare Olympic (gas turbine) engines needed. It developed this tool at the request of the operating forces and turned it over to them. In this case, the group was tasked by the Assistant Chief of Fleet Support. I was informed that this is the way it is supposed to happen, but more often than not the individuals of the group (as those of the corresponding RAF group) are self tasked. In the latter case, they are still subject to approval by the Naval Analytical Studies Committee, which coordinates the numerous groups doing operational research for the Navy.

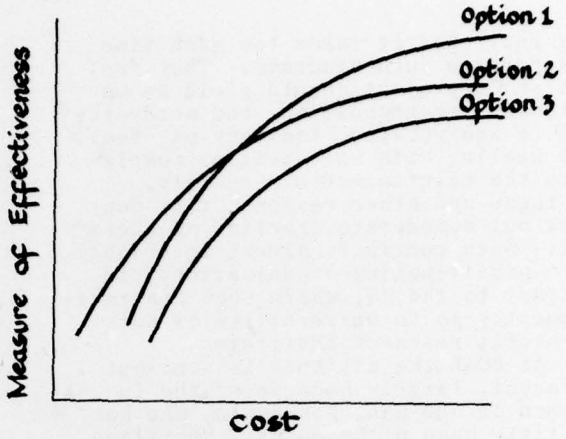
Returning to DOAE, its director is Ian Shaw, a PhD in physics, but he will have retired before this article appears in print, and Bowen will retire shortly thereafter. (Each will retire on his 60th birthday, which is normal in the British Civil Service.) Thus, the thrust of the organization could easily change in the near future. The organization is divided basically into two groups: Maritime, under W. Ramsey; and Land/Air, under D. Andrews. The names of the groups under Ramsey are illuminating. He oversees the computer group, and two analytic groups: Sea/Air 1, P. Sutcliffe; and Sea/Air 2, G. Lorimer. Under Sutcliffe are three groups: Antisubmarine Warfare, N. Wood; Surface Surveillance, J. Appleton; and Maritime Force Structure, P. Covey-Crump. Under Lorimer there are also three groups: Antiship Warfare, E. Richards; Maritime Air Defence, R. Forder; and UK Air Defence, T. Lord. These groups

typically have one military officer and three civilians.

It is clear from these titles that the analytic efforts are highly compartmentalized. As the only uniquely OR establishment in the Ministry of Defence, the DOAE has considerable freedom in the kinds of studies it carries out. Its personnel state proudly that they do "top of hierarchy of studies," as distinct from the "one-on-one studies" done in the R&D Establishments. They work "with the operational requirements," while those at the R&D Establishments work with the procurement people. "We feed on the procurement branch and supply advice to the operational people" Ramsey told me.

Thus, DOAE builds mostly simple models. There are no large mathematical programming optimizations, for example. The researchers do use Monte Carlo simulations rather commonly. An example is a simulation of a submarine attacking a group of ships that are protected by a group of war vessels; they are looking at the interaction between the submarine and the close escort screen, using duct sonar (a recent sonar concept involving thermal ducts in the ocean for sound transmission). A second model is similar, but they are looking at a passive system (e.g., sonobuoys) deployed further out. They decide where to put the sonobuoys, how well a force of helicopters can cope with detections at long range, and the number of helicopters needed to carry out this function.

The following diagram is a paradigm of the kind of conclusion toward which they like to work. If the system turns out to be describable in this way, then they can go to their principals and say: "Option 3 is never good and should no longer be considered; whether option 1 or option 2 is best depends on how much you want to spend in total; if you have a lot of money, go for option 1; if you want to do it on the cheap, go for option 2."



While the major part of their work is concerned with procurement issues, they tend to analyze rather than synthesize. The corresponding groups in the US military would, I believe, be more likely to design an optimal mission within the state-of-the-art, then the ordnance and electronics to carry out that mission, and finally the airframe or other vehicle to complete the weapons system. The DOAE seems more likely to study various configurations that have been designed elsewhere and decide which one would have the greater operational effectiveness. This kind of comparison is done on a rather competent basis, replete with the all-important sensitivity analysis, although the organization does not seem to be using any sophisticated or recently developed techniques, such as multiple-criteria optimization, which might be relevant to the systems they are evaluating.

Part of the difference is in the military with whom the analysts are dealing. In the US, most of the relevant officers in the military are highly sympathetic to OR, and a surprisingly large number of them actually have education at the graduate level in this subject. The British military officer is much less likely to have understanding or sympathy for this approach. As one of the senior scientists explained it to me, there are some situations where a decision must be made—for example, between two competing tanks—and the analysis done by DOAE is one input, and they hope a helpful input. They know they can't predict exactly how things would work out in a war, but they can simulate a sort of average war, and in such a simulation it is quite probable that one tank will come out looking better than the other. The analysts understand what kinds of assumptions go into this comparison, and they just hope that the military decision makers take those assumptions into account.

Nowhere in the Ministry of Defence does there seem to be anything corresponding to the Assistant Secretary for Program Analysis and Evaluation in our Office of the Secretary of Defense.

(This used to be called the Assistant Secretary of Defense for Systems Analysis, and did massive simulations and monumental analyses.) This organization in the US performs high-level studies in which, for example, it advises the Secretary of Defense on force levels ten and twenty years hence. If there are OR groups doing the same sort of analysis at the UK's Ministry of Defence, I was unable to locate them. (Robert E. Machol)

SEARCH IN THE ALGARVE

Praia da Rocha, on the Algarve coast of southern Portugal, was the setting for a NATO Advanced Research Institute (ARI) on Search Theory and Applications. About 40 experts found their talents being utilized in a very hard-working conference. "Search theory" means different things to different groups of investigators. The ARI had several general sessions, but for the most part of a week, split into three groups, organized under the following titles: Search and Rescue (SAR), Surveillance/Fishing, and Exploration.

In the past, most effort has been devoted to the development of methodology in searching for an object or a target. This methodology received a fair share of development in WWII, where it was motivated by the search for German U-boats. Present and very active at the meeting was Dr. Bernard O. Koopman (Professor Emeritus of Mathematics, Columbia Univ.), who was responsible for much of the methodology developed in WWII and thereafter. A compendium of the work done in the period 1942-1945 was written by him in 1946 as an Operations Evaluation Group (OEG) report. An enlarged and revised edition is now in press and is scheduled to be published shortly by Pergamon Press, Inc., New York.

Since Koopman's original report, the subject has grown and ripened into a field with an extensive body of results. Those who have been developing the theory over the last 15 to 20 years have been motivated by and worked on real problems; for example, the search for the sunken submarine SCORPION, and the search for the H-bomb lost off the Spanish coast. In 1975 a rather esoteric volume bringing much of the theory up to date was authored by L.B. Stone, a co-chairman of the ARI, and published by Academic Press, New York, under the title *Theory of Optimal Search*.

At the present time, some of the methodology has been translated into software programs that are employed by the search and rescue (SAR) elements of the US Coast Guard, US Navy, and US Air Force. Reasons for search, of course, embody many more categories than missing persons, although this represents a large effort for the Department of Defense SAR units. There can be search for floating objects, for forest fires, criminals (police operations), minerals, oil and gas, sources of infection and vectors, candidates for treatment of disease, and, of course, undercover activities in connection with hostile systems, such as missiles, mines, submarines, and hostile land operations. One major reason for the ARI was to see what commonality there was in search methods developed over the three major categories previously mentioned.

In the language that follows, we are probably borrowing heavily from the theorists in SAR, but as we outline the basic elements in search, it is conceivable that they pervade all kinds of search. There are first the nature and attributes of a target in terms of its detectability, its *a priori* location probability distribution and, in some cases, its kinematic effects, namely its changes in position and state. Arrayed against this is the nature of detecting equipment, such as physical characteristics and effectiveness (radar, sonar), platform and its mobility (helicopter, submarine). A third element is the quantity and rate of application of searching effort for which there must be a trade-off between coverage and precision. For example, if the expected number of detections are equal, two search algorithms may be said to be the same in coverage, but the area of coverage required to give this expected value helps determine precision in the comparison between two search algorithms. Another factor that plays a role is in the distinction of types of search. There may be passive observations, that is, the process of search changes nothing but the searchers' knowledge; or there may be active observations, which alert and change environment. There is always the one-shot search in which only one single trial is possible and meaningful. For example, a lost lifeboat with only one day to detect it.

The ARI included special search topics in its sessions. A fascinating account was given by Robert Grasty (Canadian Geological Survey) of the search for Cosmos-954. This was the Russian satellite embodying a nuclear reactor that fell in northern Canada. Through knowledge of its trajectory, the impact area was known to be 500 miles long and 30 miles wide. Flights were made at heights of 1500 ft, and a spectrometer was used at 1000-ft separations to attempt detection of the bits and pieces. The spectrometer was used for natural gamma-ray spectra and fission product spectra. What was required was an anomaly in the spectrometer to locate pieces of Cosmos-954 which, it developed, fell in a belt 10-km wide. There were scattered pieces all over and some small particles as much as 200 miles away. Three American and one Canadian spectrometers were employed by a joint search force of several Canadians and a hundred or so Americans.

Several intriguing applications were discussed at the ARI. How much can optimal search improve present methods in tuna fishing? There is a belief that present search is near optimal. In tuna fishing, about 70% of the time is spent searching. The tuna have 4 to 5 types of distributions of movement, and, of course, optimal search pattern depends on these distributions. South African investigators reported that they also spend 70% of the time searching for fish in their fishing expeditions. It requires a ton of fuel to catch a ton of fish, as a broad rule of thumb. Counting caribou in Canada is a search problem. Present methods of keeping track of size and location of herd in order to protect them are not well organized. Having more information on caribou is important, for example, in connection with the new highway that stretches through northern Canada.

There are interesting discrete models of search theory. In one model, a single object is hidden in one of, say, r boxes. The k^{th} box contains the object with probability p_k, has overlook probability a_k, and the cost of search in the k^{th} box is c_k. A search strategy to find the object is required. A typical result here is that the expected cost of the search is minimized if the j^{th} search of box k is in place i; if, among the numbers $p_k a_k^{j-1}(1-a_k)/c_k$, the $(j,k)^{th}$ is the i^{th} largest. In a second model, there can be any number of objects from 0 to n. In this case, each box k has an object with probability p_k independent of what the others contain. This is different from the first model, where the sum of the p_k equals 1. The search strategy takes the same form as before. One minimizes the expected cost of finding an object by putting the j^{th} search of box k in place i if among the numbers $[(1/p_k a_k^{j-1}(1-a_k))^{-1}][1/c_k]$, the $(j,k)^{th}$ is the i^{th} largest. Both of these models were reported by Jay Kadane (Carnegie Mellon Univ.).

These idealized search models have specific applications in industrial quality control testing, where an item is subject to n different tests, all of which it must pass to be acceptable, and one wishes to discover a defective component. In each case, we are concerned with the optimal strategy as to which components are to be tested first. The same can be so in managing a research and development project, where distinct parts of the project have to be done right in order for the project to be successful. Another practical situation is in scheduling oil well workovers. In this problem, there are n oil wells that could benefit from "workover" by an oil rig. The question is, which wells should have the workover first, second, and so on, especially when for the n oil wells there are m rigs available.

One of the most fascinating search problems was presented in a paper by Peter Kolesar (Columbia Univ.) on the detection of vision loss in those suspected of glaucoma, in which people with high intra-ocular pressure are candidates for actual vision loss. Since such loss is not reversible, it is very important to detect it as quickly as possible after such loss begins. In testing for glaucoma, the ophthalmologist presents a series of targets to which the individual responds and in this way maps out the field of vision for the individual. For a normal eye there are contours of constant sensitivity to light (isopters) that are rather regular (somewhat elliptical) in shape. For those with glaucoma blind spots are indicated among rather irregular contours for lines of constant sensitivity to light. These blind spots are called scotomas. Since the testing takes time and one wishes to be efficient, a goal is to find an optimal sequence, or at least a good sequence, of test locations and target sizes. Obviously,

we wish a high probability of early detection of vision loss with a modest amount of effort. In mathematical jargon, we look for a finite, well-spaced set of candidate test points, say J = 1, 2 up to N, denote V_j as the event that the eye has vision at Point J and $D_j = V_j^c$ as the event that a vision defect exists at Point J. We wish to detect at least one defect, and therefore desire to select a subset of size T that will maximize the probability of this event. A solution to this problem was presented by demonstrating its analogy to an integer programing model and then employing existing algorithms for its solution.

One of the most amorphous areas for application of search methodology is the search for minerals or oil. It may be instructive to contrast search for oil, that is, exploration, and search for lost objects. The size of an oil basin is quite variable and can be quite large; for example, the Brent field in the North Sea is 50 mi^2 and is estimated to contain 15 billion barrels of oil. Even if a lost object is an ocean liner, this would be quite small when compared to an oil basin. Oil basins are usually multiple in number whereas the lost object is often a single object. In terms of prior knowledge, the presence of an oil basin is at most a secondary trace. For lost objects we are positive about their presence somewhere. The description of the oil basin is conjecture, whereas for the object it is often available. The location of an oil basin is vague, and for the lost object there is some subjective distribution. This sums up prior knowledge.

We now continue other types of contrasts between search for oil and search for lost objects. The length of search can be many years for one basin area. For a lost object it is usually hours or days. For an oil basin there is ample time to keep detailed records as the search progresses. For a lost object, speed may limit the accurate logging of the search. For a lost object there is usually quick action in response to a crisis situation. For the oil basin there is detailed work to make best use of the resources for a specific search. The cost for exploration of an oil basin is, of course, in multiple millions. For lost objects it is many orders of magnitude lower. For an oil basin size, orientation and commercial value are exceedingly important. For a lost object the state of distress and the ease of recovery are the important factors. Thus there are enough differences to suggest that the search methodology for exploration has to be quite different.

A search for minerals housed in nodules on the ocean floor may borrow from SAR techniques. At present, sweeps of the ocean floor in the Pacific are being undertaken by American, German, and French expeditions to capture manganese, zinc, and other minerals. It is still too early to assess the success of this search and appropriate search methods.

The Proceedings of the ARI are expected to be in manuscript form in the summer of 1979. It is not known yet who the publisher will be, but the NATO Science Committee (Autoroute Brussels-Zaventem, Brussels 1110, Belgium), will be able to provide the answer when it is known. The co-directors of the ARI were Professor Brian Haley (Univ. of Birmingham, UK) and Dr. Lawrence Brown (Daniel Wagner Associates, US). About half of the participants were from the US, the remainder from the UK, France, and Germany, with a smattering from Canada, South Africa, and Japan. There are some investigators also in the Scandinavian countries. At present it seems largely an American exercise and, of course, much of the early development emerged in the US.

As mentioned at the beginning, this was a very hard-working group, despite the attractions of the Atlantic Ocean beating upon the beach of the hotel in which the ARI took place. The NATO ARIs are a rather new development and are in contrast with their better known Advanced Study Institutes (ASI). The Portuguese venture suggests that these endeavors are very worthwhile. (Herbert Solomon)

ONRL REPORTS

See the back of this issue for abstracts of current reports.

SPACE SCIENCES

SOME SPACE ACTIVITIES IN BELGIUM

Space research and development began in earnest in Belgium in 1962 with the necessity to find a means of participating in the then evolving European space program. An official space program, instituted in 1964 via the Ministry of Economic Affairs, aimed to exploit Belgium's long-standing high technology aircraft program. Specifically, the expertise in airframes, hydraulics, and electronics gained from aircraft manufacturing was directed towards the development of spacecraft structures and hydraulic servo valves. This resulted in the realization of a capability to design, construct, and implement entire spacecraft hydraulic systems, and it provided several Belgian aerospace firms with significant contract participation in the Ariane launcher program of the European Space Agency (ESA).

At the same time, the spacecraft technology program was evolving and scientific payloads for the exploration of space were being developed at several research institutes and universities in Belgium. It was during this period that the Belgian Institute for Space Aeronomy became an independent national scientific research center—a spin-off from the Royal Meteorological Institute. The Institute, a federal entity under the Ministry of Education and Scientific Research, is tasked to carry out research on the physics and chemistry of the upper atmosphere, with the aid of balloons, rockets, and satellites. As a public service, information gained through such research is classified into various categories and placed at the disposal of persons and organizations interested in space programs. Both theoretical and experimental research are being carried out at the Institute.

A large portion of the Institute's budget is currently being devoted to the preparation of three experiments to be flown on the first Spacelab. These experiments consist of: The observation of solar irradiance from the ultraviolet to the near infrared, using detectors developed at the Institute; the determination by means of a grille spectrometer of the minor constituents in the middle atmosphere having local concentrations greater than 10^9 cm^{-3}; and the determination of deuterium abundancy in the thermosphere via absolute photometry of hydrogen and deuterium lines. These experiments are consistent with historical emphasis by the Institute on space observations consisting of absolute solar irradiance measurements, ion-composition measurements in the stratosphere, and determination of vertical profiles of atmospheric constituents. Such studies have heretofore been carried out utilizing stratospheric balloons and rockets carrying scientific payload detectors developed and built at the Institute. The Institute maintains a fully equipped ground laboratory to support space experiments, including electronic and mechanical workshops, calibration facilities, and a computer facility for analysis and data processing.

There is also a strong theoretical program, with heavy emphasis on modeling of the plasmapause and the magnetosphere in general. A computer code is currently being developed to calculate and trace the trajectories of plasma density irregularities in the magnetosphere. The motions of these plasma density enhancements or deficiencies depend on the electric and magnetic field models assumed in the magnetosphere. The plasma interchange velocity is determined from a knowledge of the external forces (gravitational, inertial and magnetic) acting on the mass element, with the planetary distribution of the ionospheric conductivity (using the model developed by Pederson) adopted as boundary conditions. The code also calculates the universal time evolution of the total plasma content of drifting flux tubes as a consequence of upward ionospheric ionization flow during the day and downward precipitation fluxes during the night. The computer model is currently developed to the stage where it can provide a determination of the position of the plasmapause as the asymptotic trajectory of a plasma density "hole," in satisfactory agreement with latest experimental observations. The purpose of this computer model is to compare theoretical predictions with GEOS satellite observations and provide a continuance of an overall program to examine the formation mechanism of the plasmapause.

Returning now to spacecraft technology development, S.A.B.C.A. (Société Anonyme Belge de Constructions Aéronautiques) provides a typical example of a private company engaged in such programs. As the oldest aerospace company in Belgium, it is participating in such aircraft programs as the USAF F-16, the French F-1 Mirage, and the Dutch Fokker F-27. The two largest spacecraft programs at the moment are Spacelab and Ariane. In the former case, S.A.B.C.A. is a subcontractor for the airframe and the pressurized "Igloo" box designed to contain a wide variety of experiments. In the latter, they are providing the fins and fairings for the airframe and the jacks and servo system for the hydraulic system. In both cases, S.A.B.C.A. provides the design, manufacture, and testing of these systems. This is a typical situation in which aircraft technology has been applied to spacecraft development, in an effort to capture an equitable return on Belgium's contribution to ESA.

S.A.B.C.A. also supports a substantial program in heat pipe research, development, and manufacturing, which dates back to the late 1960s. It is one of only two companies in Europe engaged in space applications of heat pipes—the other being the West German firm of Dornier. This program has resulted in the qualification of a wide range of heat pipes operating at different power levels and incorporating different fluids. Straight and curved heat pipes have been developed as well as isothermal and variable conductance pipes. Heat pipes developed by S.A.B.C.A. have been successfully demonstrated as active thermal control elements on the COS-B scientific satellite and the SYMPHONIE telecommunications satellite. Current contracts with ESA include: developing a high performance variable conductance heat pipe (VCHP) capable of 100 W-m heat transfer with temperature control within 5°C over a length of 80 cm; investigating the diode effect in a VCHP of the 100 W-m variety, i.e., the inherent characteristic of heat pipes that permits heat conduction in one direction only; and developing cryogenic heat pipes for spacecraft that carry payloads requiring operation at temperatures in the -200°C to -80°C range.

Belgium is the fifth largest contributor to ESA and supports space research and development programs via a Scientific Policy Planning Services Office that reports directly to the Prime Minister. Space research activities based on scientific payloads placed on board balloons, rockets, and satellites are generally funded as part of the particular scientific discipline to which they relate, whereas spacecraft subsystem development is funded by the ministry to which it relates (such as the Ministry of Communications). It is thus difficult to assess the actual annual space budget accurately, although one can safely assume that Belgium secures at least as much in contracts from ESA as its contribution, which was approximately $22.0 million in 1978. (Robert W. Rostron)

NEWS & NOTES

THE SWISS NATIONAL SCIENCE FOUNDATION

In January of this year, Prof. Heinrich Zollinger of the Eidgenössische Technische Hochschule (the Swiss Federal Institute of Technology, Zurich) became the president of the Stiftungsrat (the policy-making board) of the Swiss National Science Foundation (SNSF). For all practical purposes, SNSF is the sole federal supporter for research in Switzerland.

Zollinger is one of the world's authorities in the field of textile and dye chemistry. Prior to his appointment as president of SNSF he served as the chief administrative officer of ETH for four years. Despite these administrative appointments, Zollinger has continued to maintain a research program. His present research interests involve the reactions of diazo compounds and the microbiological degradation of dyes in aqueous media.

By direction of the Swiss Parliament, 88% of the funds of SNSF are allotted to the support of nonprogrammatic basic research. (The total annual budget of SNSF is SF 130 million, or about $75 million.) The other 12% are channeled into "National Programs." At this time, the latter deal with such areas as heart and circulatory disease, studies of rural vs city populations, energy, etc. It is of interest that the work dealing with energy research areas encompasses efforts all the way from socio-economic research in the consumer area to research in hydrogen technology

that ranges all the way from basic research to the storage and transport of chemical energy carriers.

This diversity is well in line with the attitude of Zollinger. For although he is a chemist, he feels that in response to national and world needs there should be more emphasis on research in the social sciences and humanities. At the same time, he recognizes that an increased emphasis in the environmental and engineering sciences will be necessary. (George M. Wyman, USARSG)

A SITUATION IN WHICH MOHAMMED QUITE EASILY COULD MOVE A MOUNTAIN

Fully loaded 250,000-ton supertankers traveling through the channel approaching Rotterdam harbor can be damaged by insignificant swells only one meter high. The channel is oriented east and west. Swell that is generated by storms in the northern part of the North Sea, or comes into the North Sea between Scotland and Norway from storms in the Norwegian Sea, is traveling in a southerly direction by the time it reaches the Netherlands. It is traveling at right angles to the channel to Rotterdam and hits the supertankers broadside. If the period of the swell is between 12 and 16 sec, it is at or near the natural rolling period of the supertankers. As each successive crest hits the side of a ship, the ship will begin to resonate and the magnitude of the rolling of the ship will be all out of proportion to the size of the swell, while heaving and pitching occur as well.

Although the designed depth of the channel is 20% greater than the 20-m draft of the supertankers, the edges of the bottoms of the tankers, with their almost rectangular cross sections and beams of 50 m, would theoretically hit the bottom when the tilt is only 10°.

These tankers are allowed to enter the channel only during the 4-hour period of local high water (tidal range about 1.5 m). But even then, when a swell has significant wave height (the average of the highest one third of the waves) of only 1/2 m, the safety threshold is reached with tilts up to 3-5° and the tankers are not allowed to enter the channel. This situation occurs a small number of times every winter.

The Dutch government, through the Royal Netherlands Meteorological Institute, has gone to a great deal of effort in perfecting an operational system to forecast swell heights and periods off the coast from real-time and prognostic weather maps. These regular forecasts are used to control the movement of supertankers in the shallow water. (Wayne V. Burt)

275TH SCIENTIFIC MEETING OF THE CHALLENGER SOCIETY

The 275th Scientific Meeting of the Challenger Society held in Wormley, Surrey, at the Institute of Oceanographic Sciences had as its principal topic "Current Measurements at or near the Sea Surface," a very timely and important subject. I had high hopes that some new information would be presented but was disappointed. The problem is to measure the residual (mean or average) currents at or near the sea surface, where the desired signal may be an order of magnitude less than the noise due to wave motion, turbulence, or convection. Tracking of neutral density floats, which is not new, seems to have more promise than any other direct method, but it is too expensive for routine use or use over any extended period of time.

One of the oldest methods when coupled with remote sensing seems to give good results. Over one hundred years ago the US Navy hydrographer M.F. Maury enlisted the help of the world's merchant fleet. Each of the participating ships determined its estimated position by dead reckoning (DR) and then assumed that the vector differences between the DR positions and the positions determined by celestial navigation were an indication of the mean currents. Now we use very precise hull-mounted or towed electromagnetic sensors that give a ship's true speed and direction both forward and sidewards (windage) through the water. Satellite-navigation fixes about once an hour give the ship's correct position very accurately. This information is fed into a computer that prints out a current vector each time the satellite fix is recorded. Woods Hole Oceanographic Institution and the British Institute of Oceanographic Sciences have collaborated in developing this system so it can be used on merchant ships. It was

successfully tested in a trip across the Atlantic Ocean last September. (Wayne V. Burt)

PERSONAL

The Council of the Institute of Physics announced the award of the 1979 Holweck Medal and Prize to Professor A. Blandin of the Université Paris-Sud, Orsay, for his outstanding contributions to the theory of metals.

On 18 May 1979 the Operational Research Society, meeting at the Royal Society in London, conferred upon E.K.G. James the silver medal of the ORS. This is a very prestigious medal, awarded about once in every three years when a suitable recipient is found. James, who has recently retired from the Civil Service, was honored primarily for his effectiveness in bringing operational research into the service of the British government.

Mr. A.M. Lee, formerly President of the International Federation of Operations Research Societies, retired at the end of May, 1970 from Rolls-Royce Limited. He will continue to reside in Derbyshire.

The Institute of Physics, London, and the German Physical Society announced the award of the 1979 Max Born Medal and Prize to Dr. J.B. Taylor of the Culham Laboratory, Atomic Energy Authority, for his work on the theory of plasmas, particularly in relation to controlled nuclear fusion. The presentation will take place in September 1979 during the annual meeting of the German Physical Society in Ulm.

OBITUARIES

Professor John R.D. Francis, Professor of Hydraulics in the Civil Engineering Department of Imperial College of Science and Technology, London, died 25 March 1979 at the age of 58. After WW II service in the Royal Navy, he joined the College in 1946. Except for a period of several years at the Univ. of Manchester (1961-1966), he was at Imperial most of his academic career. His research work covered several fields. In the early days he was interested in interactions of wind and waves. He then moved to open channel flow, and while he was Professor of Hydraulics he specialized in various aspects of particle transport. He did not favor the trend toward elaborate and expensive apparatus, and his recent work involved small-scale and elegant experiments. He had acted as external examiner at many universities in Britain and overseas. He had been elected as President of the European Society for Engineering Education and was to have taken up this office in August.

Giulio Natta, Nobel laureate, died in Bergamo, Italy, 2 May 1979 at the age of 76. Born and educated in Italy, he began his career by teaching at the Universities of Pavia, Rome, and Turin. He joined the Polytechnic Institute of Milan in 1938 as Director of the Institute of Industrial Chemistry. In 1952, after attending a lecture in West Germany by Karl Ziegler, Natta invited him to join the Institute. Their work won for them the Nobel Prize in chemistry in 1963 for their contribution to macromolecular chemistry and for the development of new high polymers, a major advancement in synthetic materials. Natta gave up active work more than a decade ago because he suffered from Parkinson's disease.

ONRL REPORTS

C-1-79 FIFTH EUROPEAN SPECIALIST WORKSHOP ON MICROWAVE ACTIVE SEMICONDUCTOR DEVICES by I. Kaufman and A.K. Nedoluha

This report is a brief description of subjects discussed at a workshop attended by approximately 50 individuals engaged in work in microwave semiconductor devices and/or their use in circuits.

C-2-79 NATO SYMPOSIUM ON COPING AND HEALTH, BELLAGIO by J. Vernikos-Danellis

Highlights are discussed of papers presented at the Symposium on Coping and Health, held 26-30 March 1979 at the Bellagio Study and Conference Center of the Rockefeller Foundation. This Symposium was a scholarly summary by the 20 leading world authorities in the field of Stress and Coping techniques. Experimental data from animals and experimental and clinical data from humans formed the basis of the discussions.